U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 113.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.

BY

W. D. HUNTER,

In Charge of Southern Field Crop Insect Investigations,

F. C. PRATT,

Late Assistant Entomologist,

AND

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., May 3, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "The Principal Cactus Insects of the United States," prepared by Messrs. W. D. Hunter and J. D. Mitchell, of this bureau, and the late F. C. Pratt, who for many years was in the employ of the bureau.

In the work of the Bureau of Plant Industry on the utilization of the prickly pear as a farm crop it became evident that insect injury in plantings was of considerable importance. This observation was made by Mr. David Griffiths. In 1907 he brought the matter to the attention of the Bureau of Entomology and the investigation upon which the present manuscript is based was begun. During the work the bureau has profited by the close cooperation of Mr. Griffiths, and many of his observations are included in this report.

I recommend that this manuscript be published as Bulletin No. 113 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.

INTRODUCTION.

The cactus plants of the genus Opuntia are among the most striking objects to be seen in semiarid and arid regions. These plants, which are extremely picturesque, are accorded a prominent place in the illustrations and literature of early surveys, undertaken by the War Department,[1] and, from a scientific standpoint, are of great interest because they have been found to have adapted themselves to existence in regions of small rainfall in many remarkable ways. The numerous insects associated with cactus plants are naturally of great interest. These insects have adjusted themselves to the general conditions in the regions in which the plants grow and have also adapted themselves to the structure and habits of the plants themselves. Moreover, cactus insects have always held special interest on account of the cochineal insect. The cultivation of this species, which is indigenous to America, caused the prickly pear to be transported to remote parts of the globe, where it has been planted for the purpose of furnishing food for the dye-producing insect. The industry of rearing the cochineal insect was for years a very important one. It furnished valuable dyes which are still utilized for special purposes. In the Canary Islands alone, in 1876, the exportation of cochineal amounted to over 5,000,000 pounds. It has been determined that the bodies of about 70,000 cochineal insects are required to make a pound of the dried product. This gives an indication of the extent of the industry in the Canary Islands, which did not, however, produce nearly all of the supply which entered into commerce.

Except for the cochineal insect, the species feeding upon Opuntia have been until recently rather of scientific than of practical importance. In the early days, since it was necessary to cultivate the Opuntia plant as food for the cochineal insect, any species which injured the plant were of economic importance. In fact, the treatises on the cultivation of the cochineal contain directions about the control of various species which damaged the plant. With the decadence of the cochineal industry, the cactus plants became nuisances, except

[1] Pacific Railways Report, vol. 4, p. 37, 1856; U. S. and Mexican Boundary Survey, vol. 2, p. 35, 1859.

where the tunas were utilized as food.[1] They occupied land that could be used to advantage for valuable crops. In this way, in a few years, the plant was changed in character from a valuable one to a weed. Incident to this change the insects feeding upon Opuntia assumed an entirely different character. Instead of being considered pests, they came to be looked upon as beneficial on account of their destruction of the weed. In fact, in South Africa and Australia the encouragement of the insect enemies of prickly pear has been proposed as a feasible means of reducing the number of plants.

Within very recent years, at least in so far as the United States is concerned, there has been another revolution in regard to prickly pear. It has been recognized for many years in the southwestern portion of the United States that the plant furnished a supply of food for cattle during drought that frequently prevented the starvation of large herds. It was considered, however, that this was a rather poor return for the loss of large grazing areas on which the plants grew and which in normal seasons without the prickly pear would have furnished large amounts of forage. Some years ago Mr. David Griffiths, then of the Arizona Agricultural Experiment Station, began an investigation of the feeding value of prickly pear. It was soon found that the plant has a surprisingly high feeding value.[2] The greatest practical difficulty in the use of the plant for forage was the spines, but it was found to be possible to eliminate this difficulty by singeing the plants or by running them through machines which chopped them into small pieces. It was also discovered by Mr. Griffiths,[3] whose more recent work has been done as an agent of the Bureau of Plant Industry of this department, that when prickly pear is planted it responds readily to cultivation. In fact it was found that artificial plantings of the pear with only meager cultivation furnished a growth in three years that was fully as great as the growth under natural conditions in double that period. At this point, however, it became evident that the insects affecting the prickly pear would need to be taken into consideration. In fact it appeared in the experimental plantings of the Bureau of Plant Industry that the insect injury was one of the most important obstacles to the cultivation of the prickly pear as a farm crop. In this way there has been

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[1] In this discussion we consider the prickly pear as a crop planted on a large scale but do not overlook the fact that its fruit has been utilized as food for man from very ancient times and is still an important human food in large areas. There has been no revolution as regards the tuna as food for man. It has always been important. However, the tunas are obtained from wild plants, or from those cultivated on a comparatively small scale about houses, and thus represent a system of growth quite different from the extensive field culture of the early days.

[2] The Prickly Pear and other Cacti as Food for Stock, by David Griffiths. (Bul. 74, Bur. Plant Ind., U. S. Dept. Agr., March 8, 1905.) Feeding Prickly Pear to Stock in Texas, by David Griffiths. (Bul. 91, Bur. Plant Ind., U. S. Dept. Agr., 1906.)

[3] Prickly Pear as a Farm Crop, by David Griffiths. (Bul. 124, Bur. Plant Ind., U. S. Dept. Agr., February 19, 1908.) The Tuna as Food for Man, by David Griffiths and R. F. Hare. (Bul. 116, Bur. Plant Ind., U. S. Dept. Agr., December 2, 1907.)

a complete revolution in so far as the importance of cactus insects is concerned.

HISTORICAL STATEMENT REGARDING CACTUS INSECTS.

It has been stated in a preceding paragraph that the insect enemies of Opuntia attracted some attention in former years on account of their injury to the host plant of the cochineal insect. Several of the treatises on the cultivation of the cochineal contain brief suggestions about the destruction of the enemies of the plant, as well as about the enemies of the cochineal itself. In all these considerations, however, only the merest incidental attention was paid to species other than the cochineal.

The first systematic work on cactus insects that was undertaken was that done in 1895 by Mr. H. G. Hubbard, who lived in Florida. He discovered a lepidopterous larva, *Melitara prodenialis* Walk., which feeds upon the prickly pear, traced out its life history and transformations, and published a most interesting account of his observations.[1] A few years later Mr. Hubbard sojourned for some months in Arizona. In that territory he made studies of the insect fauna of the giant cactus (*Cereus giganteus*). Although plants of the genus Cereus will probably never be of importance as forage,[2] Mr. Hubbard's studies have a bearing upon insects infesting Opuntia, since the faunas of Cereus and Opuntia are largely the same. After his death, the results of Mr. Hubbard's investigations were published under the editorship of Mr. E. A. Schwarz.[3]

From 1896 to 1898, on various trips to the region then infested by the boll weevil, Mr. E. A. Schwarz made a number of observations on insects infesting Opuntia. In fact, he discovered a number of the species which have now been found to be of importance in the area in which the prickly pear is undergoing cultivation. Dr. L. O. Howard and Mr. C. L. Marlatt also made observations on cactus insects at about this time. The results of these incidental observations were published in notes in the Proceedings of the Entomological Society of Washington.

By 1905 Mr. David Griffiths had begun the cultivation of the prickly pear in the vicinity of San Antonio, Tex., and elsewhere. It was on his experimental plantings that the observation was made that the concentration of the plants under cultivation seemed to increase the amount of insect injury. Recognizing the importance of this matter, Mr. Griffiths immediately began the collection of specimens which, with full notes, were transmitted to the Bureau

[1] Proc. Ent. Soc. Washington, vol. 3, pp. 129–132, two figs., 1895.

[2] The Cereus plants are, of course, utilized in many ways by the inhabitants of the region in which they occur, but not as forage.

[3] Psyche, May, 1899, Supplement, pp. 1–14.

of Entomology at Washington. This material was placed in the hands of Mr. E. S. G. Titus and Mr. F. D. Couden. In spite of the difficulties of rearing the specimens, due to the transportation to Washington and the utterly different climatic conditions, these entomologists succeeded in rearing a large number of specimens. This material, with the rearing notes and the field notes supplied by Mr. Griffiths, has been used in the preparation of this bulletin.

In 1907 Mr. Griffiths' field observations more than verified his previous impressions regarding the importance of cactus insects. By this time it had also become evident that the rearing work could be carried on to much better advantage in the regions where the Opuntia was grown and that field experiments in control were necessary. For these reasons, in 1907 the investigation was turned over to the branch of Southern Field Crop Insect Investigations. In connection with other work Mr. F. C. Pratt and Mr. J. D. Mitchell were detailed to institute an investigation of cactus insects in Texas. Mr. Pratt's work was continued with serious interruptions, due to his ill health, from late in 1907 until the fall of 1910. During this time he and Mr. Mitchell accumulated a very large amount of information about the insects associated with the Opuntia plant and regarding feasible means of control of the more injurious species. The original intention was that a publication on this subject should be prepared by Mr. Pratt. His ill health, which became acute about the time that sufficient material had been gathered to form the basis of a bulletin, and his death soon afterwards, prevented placing the matter in form for publication. This part of the work has been done by the senior author, who has also made some field observations, although the great majority of such observations were made personally by Mr. Pratt and Mr. Mitchell.

NUMBER AND CLASSIFICATION OF CACTUS INSECTS.

As the result of the work we have done and that of the previous investigators who have been mentioned, 324 species of insects are known to be associated with the cactus plant. These divide themselves naturally into five categories, as follows: Species injuring the plant, 92; parasites of injurious species, 28; scavengers, 73; flower visitors, 40; species only incidentally associated with the plant, 91.

The injurious species affect different parts of the plant. In fact, no important part of the plant is immune from injury. Twelve species are known to attack the roots or stem. Twenty-seven species attack the joints, of which 11 species feed inside of the joints while 16 destroy the outer portion. A considerable number are found in the blooms; a few of these are injurious, but others undoubtedly assist in the fertilization of the plant. The fruit is injured by 13 species.

LONGICORN BEETLE, MONEILEMA CRASSUM, AN IMPORTANT ENEMY OF PRICKLY PEAR.

Adults feed on exterior of joints of the cactus, while the larvæ destroy the interior of both joints and stems. Enlarged. (Original.)

WORK OF LONGICORN BEETLE, MONEILEMA CRASSUM, ON THE CACTUS, ECHINOCEREUS SP. (ORIGINAL.)

The foregoing arrangement of five categories will be followed in the body of this bulletin. Within these categories the species will be treated in the order of their importance. In this place, however, we shall include a list of the principal species arranged as they rank in importance regardless of the parts of the plant affected.

THE PRINCIPAL INSECTS INJURIOUS TO OPUNTIA IN ORDER OF THEIR IMPORTANCE.

1. Chelinidea, 3 species. Feeding upon the joints externally.
2. *Mimorista flavidissimalis* Grote. Attacking joints externally at first but later invading inner portion.
3. Narnia, 4 species. Feeding on joints externally.
4. Melitara, 4 species. Feeding within the joints.
5. Moneilema, 8 species. Feeding within joints and stems.
6. *Dactylopius confusus* Cockerell and *D. tomentosus* Lamarck. Feeding on surface of joints.
7. *Marmara opuntiella* Busck. Forming mines beneath surface of joints.
8. Asphondylia, 3 species. Feeding on interior of fruit.
9. *Stylopidea picta* Uhler. Feeding on surface of joints.
10. *Diaspis echinocacti cacti* Comstock. Feeding on surface of joints.
11. *Ozamia lucidalis* Walker. Infesting the fruit.
12. *Platynota rostrana* Walker. Feeding within the fruit.
13. Polistes, 3 species. Feeding on the fruit.

INSECTS AFFECTING THE ROOTS OR STEMS.

Species of the Genus Moneilema.

Among the insects which affect the roots or stems the most important forms are eight species of the cerambycid genus Moneilema, to which the common name "Opuntia longicorns" may be applied. These are wingless, robust, shining black beetles,[1] from about 15 to 25 mm. in length. (See Pl. I.) They are to be found upon the Opuntia plants as adults throughout the season. In the adult stage they do considerable injury by gnawing the edges of the newly formed joints. This injury, however, is insignificant in comparison with that done to the stems and roots by the larvæ.

The most important species of Moneilema in Texas are *M. crassum* Le Conte and *M. ulkei* Horn. These are widely distributed in the State. Other species are included in the list at the end of this bulletin.

It is interesting to note that the work of the adult beetle sometimes results in the dissemination of the plant. Frequently the beetles cut

[1] One species, *ulkei*, is opaque, its surface mottled with whitish.

at the base of a newly-formed joint, so that it is soon broken from the plant. In some cases the joints thus separated from the plants take root upon falling to the ground. As a matter of fact this accidental planting by the Moneilema beetles is one important cause for the growth of the prickly pear in very dense clusters around the old plant.

DESCRIPTION OF THE LARVA OF MONEILEMA CRASSUM.[1]

About 12 mm. long when full grown. Body white, with a dark-brown chitinous head and with a pale-yellow semichitinous prothoracic area. Head transverse, rounded oblong, with the labrum, sometimes the labium, and the maxillæ light yellow in contrast to the dark-brown mandibles and occiput. Eyes obscured. Antennæ single jointed, very small, placed immediately behind the mandibles. Labrum and clypeus transverse; mandibles large, apically emarginate, distant; maxillary and labial palpi small. Body sparsely covered with brown setæ. Prothorax tumid, twice as large as either mesothorax or metathorax. Mesothoracic spiracles plain. Abdomen 10-segmented, the last 2 modified, forming the anal region; first 8 segments provided with large, round spiracles; first 6 dorsally prominently bituberculate; first 7 ventrally transversely grooved.

These larvæ infest the main stem and older joints of the prickly pear. The gallery is wide and soon becomes blackened. The frass frequently becomes infested with dipterous larvæ of various species. The larvæ are capable of considerable movement and have been found frequently to travel from one part of the plant to another in order to obtain a better supply of food. After attack the plant appears sickly and shows copious exudations of black sap which becomes so hard that it can be cut with a knife with great difficulty. The appearance of this black exudation is shown in an accompanying illustration (Pl. II).

The larva makes an imperfect cocoon, in which transformation to the pupa takes places. These cocoons consist of an inner layer of fiber of the cactus plant covered with sand. The texture is very firm. They measure 25 by 35 mm. They are generally found just beneath the prostrate joints on the ground. The duration of the immature stages was not determined, but it is evident that there is only one generation during the season. Adults appear most commonly in April and May and in September.

As the Moneilema beetles are among the more important insects of the prickly pear, it may be necessary to combat them in plantings. Three means of attack are in evidence from the account that has just been given, namely, burning, hand picking, and poisoning. The larvæ and cocoons can be destroyed by burning the prostrate portions of the plants. The injury can always be located by reason of the large number of joints and stems that have fallen to the ground. A

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[1] Prepared by Mr. W. D. Pierce.

little work in raking together and burning the fallen portions of the plant where they are numerous would serve to hold the insect in check. If this practice has not been followed, it will still be possible to check injury with some satisfaction either by poisoning the adults or by collecting them by hand. On account of their large size and sluggish movements and the fact that they are without wings, hand collecting is not difficult and will be very effective. This process would generally be preferred to that of poisoning on account of its cheapness. When poisoning is practiced, arsenate of lead should be used. It should be applied, in powdered form only, to the young and tender joints, as the adults feed upon no other parts of the plant. The poisoning of these young joints will also serve to control at least one other important enemy of Opuntia, as will be described later.

A Cutworm.

On several occasions a cutworm, *Chorizagrotis soror* Smith, has been found to do considerable injury to Opuntia plants. The damage is greatest in the case of young plantings. The pulp that is exposed in cutting the joints into suitable pieces for planting seems to attract these worms. In one of the plantings at San Antonio, Tex., they ate canals through the underground portions of the plants. They are partial to the varieties of more tender structure. Whenever this insect is abundant it will be easy to protect the plants by soaking the portions used for seed for a few minutes in a solution of arsenate of lead, or, if more convenient, the sections to be planted could be dusted with the powdered arsenate of lead at the time of planting.

Coccidæ

The only other insects which have been found attacking the roots of Opuntia plants are three species of Coccidæ, or scale insects. None of these species has been found to be abundant or to have any marked effect upon the vigor of the plant in the localities in which they occur. It is consequently unnecessary to give them further attention.

SPECIES ATTACKING THE JOINTS EXTERNALLY.

Chelinidea vittigera Uhler.[1]

The coreid bug, *Chelinidea vittigera* Uhler, may be readily recognized from the following brief summary of its appearance and habits:

It is a yellowish bug resembling the common squash bug (*Anasa tristis* De Geer) in general appearance (fig. 1), about 15 mm. long,

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[1] Order Hemiptera, Family Coreidæ.

feeding generally gregariously on the joints of Opuntia and allied genera. It is chiefly nocturnal in its habits. The first indications of feeding are the occurrence of lighter circular spots on the joints. The whitish excrement of the insect, which covers the surface of the joint, is also conspicuous. During the winter the insects are to be found in large numbers in a somewhat dormant condition under prostrate joints.

This species and its congeners are restricted to cactus plants and are by far the most important Opuntia insects occurring in the United States. On account of the wide distribution and prolific breeding of *C. vittigera* it is conspicuous in all localities where it occurs. Within its range *Mimorista flavidissimalis* Grote is probably more destructive to the plants, but that species is restricted to a comparatively small portion of the area occupied by Opuntia.

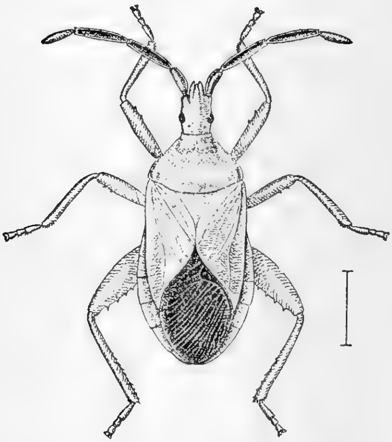

Fig. 1.—A cactus insect, *Chelinidea vittigera:* Adult. Enlarged. (Original.)

NATURE OF INJURY.

The small circular discolorations on the joints resulting from the work of this insect do not appear until feeding has progressed for some time. As soon as they do make their appearance, however, they are extremely conspicuous. They may be found upon only a few joints of a plant, or where the bugs are more abundant all the joints may be affected. As the injury proceeds, the spots become larger and coalesce, so that the whole area of the epidermis assumes a deadened, yellowish, and pitted appearance. The whitish excrement is discharged more profusely when the bugs are approached and may possibly have some protective effect.

As a result of attack the plant is weakened so that it soon falls over. Where the bugs are numerous the fallen plants give somewhat the same appearance as they would if battered down by heavy hail. In some cases, where the attack is not strong, portions of the fallen joints take root and give rise to new plants. More frequently, however, the joints are unable to recuperate and either dry up completely or become the breeding places for the many species of scavenger insects found associated with the cactus plant.

As soon as the bugs, whether in the nymphal or adult stages, have weakened a plant they migrate to other plants and continue the work of destruction.

It has been observed by Mr. J. D. Mitchell that the joints upon which the bugs have fed, and which may not have shown any special damage during the season, are the ones first injured by frosts during the following winter. This indirect injury sometimes results in setting the plants back by as much as the growth of two years. Another form of injury which is suspected but not proven in the case of this bug is the dissemination of the fungous disease *Perisporium* sp. This disease causes large black spots on the joints. The infected area frequently drops out, leaving a more or less circular opening through the joint. The feeding habits of the bug are such as to render it very likely to plant the spores of the fungus when it travels from one joint to another.

This species was first called to attention as an enemy of Opuntia by Mr. F. W. Thurow, who, in March, 1893, reported to the Department of Agriculture that three species of Opuntia growing in Harris County, Tex., were greatly damaged.[1]

DISTRIBUTION.

This species is not confined to the prickly-pear region proper, although there is no doubt that it greatly prefers that plant and that it is much more abundant where the Opuntia occurs in large numbers. Its western limit in Texas, so far as ascertained, is Brewster County. In the east it occurs along the Gulf and inland as far as Trinity County, Tex. It has been taken in Dallas and Parker Counties, Tex., wherever Opuntia occurs. It has also been observed in California, Utah, and Colorado, and in fact is generally distributed throughout the Western and Southern States. In the East it is found in Louisiana, Alabama, and North Carolina and has been recorded from Virginia.

VARIATIONS.

The following notes on variations in *Chelinidea vittigera* have been furnished by Mr. O. Heidemann, who examined all of the hemipterous insects taken on cactus:

> The species is exceedingly variable in structure of the body and in color. The relative length of the head, described by Prof. Uhler as being two-thirds the length of the thorax, can hardly be considered as a constant character. There are specimens which have the head and thorax subequal in length or equal. The peculiar prism-shaped antennal joints are more or less dilated, in some examples very conspicuously. This variation in the dilatation of the antennal joints is noticeable even in those specimens marked as reared from Opuntia. The color of the antennæ, elytra, and legs varies considerably, changing from reddish-brown into black. The darkest, most developed forms occur in Colorado and Utah.

[1] Insect Life, vol. 5, p. 345.

LIFE HISTORY, AND DESCRIPTION OF STAGES.

The breeding of this insect in the cactus area begins early in the season. At San Diego, Tex., in March, Mr. J. D. Mitchell observed that the first brood had appeared. In April the first young were noticed in Victoria County. The bugs breed continuously throughout the summer and fall. Owing to the fact that certain individuals are retarded in their development no definite number of broods is determinable. It has frequently been observed that some specimens reach the adult stage before others from the same mass of eggs have passed the third nymphal stage. This explains the observation of many persons that the bugs can be found in all stages on the plants at all times except during cold weather.

The eggs are deposited generally on the spines, although in confinement the females deposit on the sides of rearing cages and in some instances eggs have been observed on the sides of dead as well as of living joints. The spines, however, are undoubtedly the normal place for deposition of the eggs. (See Pl. VII, fig. 2.) During the summer season 5 adults produced 198 eggs in 15 days, averaging practically 40 to the individual. These females were not reared, so that it is more than likely that the capacity for egg laying is much larger than the figures would indicate. The method of oviposition was observed by Mr. C. E. Hood. He noted that the female begins by rubbing the spines or surface on which the eggs are to be laid with the tip of the abdomen, probably discharging a sticky substance. After the egg is about halfway protruded a circular motion of the abdomen is observed. The female then appears to rub the egg over the spine before finally discharging it. In this manner 4 eggs were deposited in 6 minutes. It was observed in the breeding cages, and frequently in the field, that the eggs are not securely fastened to the spines. The attachment is so weak that they fall as the result of even a slight disturbance.

THE EGG.

Length, 1.25 mm.; width, 0.75 mm. Dark brown, opaque, very finely and uniformly punctured, mottled with a whitish exudation. Elliptical; lid subdorsal, large elliptical. Placed with great regularity about 0.5 mm. apart on spines, with longitudinal axis parallel to spine, each string of eggs from 6 to 25 mm. in length. Duration of egg period, from 12 to 20 days.

THE NYMPHAL STAGES.

First instar.—Length, 2 mm. Brownish black, except abdomen, which is pea-green in some individuals and a dark crimson in others. The former variety shows a slightly red callosity and margins. Antennæ 4-jointed; club short; first joint slightly flabellate; second joint scarcely one-third longer than the third; first and second joints with apical tips terminating in short spine. Head produced, bifurcate. Length of stage, 7 days.

Second instar.—Length, 4 mm. Very little change from first instar except that the femora and prothorax have a slightly lighter color. Second joint of antenna with almost straight sides. Spines on first and second joints more pronounced. Length of stage, 4 days.

Third instar.—Length, 5.5 mm. Spines on first and second antennal joints slightly more pronounced, as is the raised callosity on the abdomen. The two transverse brown slits very conspicuous. Prothorax changing to greenish. Antennæ more distinctly flabellate; otherwise there is little change. Length of stage, 4 days.

Fourth instar.—Length, 6.5 mm. Greenish color on abdomen decidedly darker; legs, antennæ, head, and thoracic spines olivaceous black. No change in spines. Length of stage, 12 days.

Fifth instar.—Length, 7.5 mm. The abbreviated wing-pads appear and extend over the two anterior abdominal segments. General color dull olivaceous black, except tips of antennæ, which are orange. Prothorax considerably wider, thus altering the appearance greatly, as the previous stages have a very narrow prothorax in comparison to the abdomen. Length of stage, 14 days.

The duration of the fourth and fifth instars was determined during October; that of the earlier stages in July and August. Undoubtedly the duration of the last stages in summer does not greatly exceed that of the earlier ones.

DIMORPHISM.

In the examination of several thousand of these bugs which have been under observation in the field and in rearing cages it was noticed that there was a great variation in the color of the adults from different localities. This variation is much more noticeable in the nymphal stages. The color of the abdomen is either pea-green or dark crimson. Repeatedly experiments in breeding these color variations resulted in rearing adults which could not be distinguished.

HIBERNATION.

At a temperature from 45° to 50° F. these bugs appear to be restless, congregating at times, and at other times dispersing in order to find suitable quarters for hibernation. Throughout the winter they are to be found in numbers under fallen cactus joints, in the trash that accumulates at the base of the plants, under grass roots, and in fact wherever they can obtain shelter in the immediate vicinity of the Opuntia. They do not seem to travel any considerable distances from the plant upon which they were produced.

Chelinidea tabulata Westwood

The species *Chelinidea tabulata* Westwood has often been observed in company with *Chelinidea vittigera.* It is not common, but if it were it would easily rank as a pest of prime importance on Opuntia. It is a Mexican species hitherto not known to occur in the United States. In our collections it has been taken at many localities from Austin, Tex., southward and westward.

Chelinidea sp.

A third species of the genus Chelinidea was taken in May at Tuscon, Ariz., on *Opuntia arbuscula*, *O. versicolor*, and *O. fulgida*. This species is somewhat smaller than the preceding. Rearing experiments were unsuccessful on account of the shipment of the species into a region of different climate.

The Control of Chelinidea vittigera and Allied Species.

Two features of the life history of these bugs reveal feasible means of control. These are the clustering of the adults during winter and the gregarious habits of the young. The best control practice to follow is undoubtedly to collect and burn the trash on which the insects are found during the winter. At that time they are almost completely dormant and can be raked into piles along with the débris and burned. The gregarious habit, which is especially well marked in the earlier immature stages, makes it easy to check the development in a different way. The use of the gasoline torch, which is found upon all plantations where the cactus is used for forage, gives an economical and effective method of destroying these stages. Whenever the appearance of the small circular spot and of the white excrement shows that the insects are beginning to injure the plants seriously, the torch can be brought into play to excellent advantage.

Mimorista flavidissimalis Grote.[1]

The cactus insect *Mimorista flavidissimalis* Grote may be recognized easily from the following description:

From one to seven yellowish larvæ feeding invariably on upper edge of young joints of Opuntia under a silken web, sometimes penetrating the interior. (Pl. III.)

After the Chelinidea bugs, this insect is the most important enemy of Opuntia in the United States. Unlike the Chelinideas, however, it is restricted in its range. In Texas it is found from Hallettsville and San Antonio southward. West of San Antonio it is rare, but was taken at Tucson, Ariz., in May by Mr. Pratt. In the area where it is common it is by far the most injurious cactus insect.

The species was described by Grote in 1877 from specimens received from Texas. Since then it has not been recorded outside of Texas. It was not until 1905, when the present work was undertaken, that anything was known about the early stages. The first rearings were made at Washington, D. C., from material collected at San Antonio, Tex., by Mr. David Griffiths.

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[1] Order Lepidoptera, family Pyralidæ.

WORK OF MOTH, MIMORISTA FLAVIDISSIMALIS, ON JOINT OF OPUNTIA. (ORIGINAL.)

LARVÆ OF BEETLE, DISONYCHA VARICORNIS, ON OPUNTIA LEPTOCAULIS.
(ORIGINAL.)

THE ADULT.

The adult is a moth which expands about 1 inch. It is bright straw colored, with inconspicuous brownish markings arranged in four irregular transverse bands.

THE LARVA.

Length, 11 mm.; shining; general color yellowish white; legs concolorous; head and cervical shield somewhat darker yellow. Sides parallel, except for slightly raised spiracular callosities; faintly impressed median line. Two minute spots on cervical shield and spiracles black. Hairs long, sparse; most numerous on first six segments; white in color; arranged in subdorsal, marginal, and submarginal series; none on median line.

THE PUPA.

Inclosed in a whitish cocoon of thin, dense, paper-like construction; length, 9 mm.; width, 3 mm.; shining, light brown; head black. On thoracic segment one median and eight lateral fine longitudinal dark lines; the ones on either side of the median line are double for a short distance near their anterior third.

SEASONAL HISTORY.

A generation of this species is produced in about 30 days. The earliest record of the rearing was made by Mr. J. D. Mitchell on May 29 at Victoria, Tex. In that locality the second generation of the year had developed by June 26. The fifth generation matured by September 15. In all probability there is one additional brood during the season in southern Texas.

DAMAGE.

The injury by this species is confined to the young joints. Mr. Mitchell has repeatedly seen from 50 to 75 per cent of the new growth destroyed over considerable areas. The moth deposits from one to seven eggs, always on the upper edge of the joint. The first indications of injury are strings of sap exuding from the joints. If this discharge is removed a small hole becomes visible. As the larvæ develop the discharge of sap from the plants becomes mixed with silk, trash, and excrement discharged by the insects. (Pl. III.) In rare cases, when only a few eggs have been deposited, the joint recovers, although it is always deformed. In most instances, however, decay begins, and the joint turns black and finally drops to the ground.

The two features of the attack of this insect which cause it to be of great importance in connection with the cultivation of cactus are, first, the large number of broods occurring throughout the season, and, second, the attack against the new growth. Where the species is at all abundant this attack effectually prevents any additional

growth of the plants. At the end of the season there are no more joints than there were the year before.

A hymenopterous parasite of this species, *Eiphosoma texana* Cresson, has been reared. It does not appear, however, to be sufficiently abundant to exert much control over the species.

CONTROL.

Mr. J. D. Mitchell has found by experiments performed at Victoria, Tex., that it is not difficult to control the species by the early application of powdered arsenate of lead. As soon as damage becomes evident in the spring the new growth should be dusted carefully with this arsenical. In this way the majority of the first brood will be destroyed. Some of the joints infested at that time will recover and there will be little injury from the following broods. The early application of the arsenical is very important on account of the formation of the protective web soon after the larvæ have begun work. If the first brood should not be reached in time every effort should be made toward applying the poison in ample time for the second brood.

In the case of small experimental plantings the use of the gasoline torch will furnish an economical means of control. In other cases the cutting off and burning of the early infested joints will answer the same purpose.

Disonycha varicornis Horn.[1]

Disonycha varicornis Horn is a flea-beetle about 7 mm. in length. It is of conspicuous appearance on account of the brilliant polished blue of the elytra. The head and thorax are yellow; the under parts dark brown. So far as known this insect is restricted to *Opuntia leptocaulis* and *Opuntia arborescens*. It has never been found on the broad-leafed species of the genus Opuntia. It is observed frequently on its host plants in the adult and immature stages. The larvæ feed on the surface of the plants without any protective covering whatever. (Pl. IV.) Frequently they occur in such numbers as to cause the death of the plants. As it happens that the cacti attacked by this insect are not of any special economic importance, it is unnecessary to give further attention to the species.

Stylopidea picta Uhler.[2]

Stylopidea picta Uhler is a slender hemipterous insect about 6.5 mm. long. The head and thorax are bright crimson and the wing covers slate color but with narrow yellowish borders. The eyes are

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[1] Order Coleoptera, Family Chrysomelidæ, Subfamily Halticinæ.
[2] Order Hemiptera, Family Capsidæ.

placed at the end of the stalk-like prolongations of the head. The under parts are dark brownish.

The species has been collected on Opuntia from San Antonio, Tex., to the coast and southward to Brownsville, Tex. It seems to be more abundant in the vicinity of Corpus Christi, Tex., than elsewhere. The injury is not conspicuous. It causes the plants to assume a spotted appearance, but, except where the bugs are unusually abundant, the joints recover. It is not a true cactus insect, but has been found upon a variety of other plants. On account of its gregarious habits it could be easily controlled by means of the gasoline torch when it becomes unusually abundant.

The Cottony Cochineal Insect.[1]

(*Dactylopius confusus* Cockerell.)

The cottony cochineal insect (*Dactylopius confusus* Cockerell) is easily recognized by the large flocculent masses of pure white wax which covers the bodies. (Pl. V, upper figure.) When crushed the bright crimson color of the body fluid runs out and contrasts strongly with the white envelope. These scale insects are found on the joints of Opuntia, frequently in large masses.

This species is closely allied to the true cochineal insect, *Dactylopius coccus* Costa, which does not appear to occur in the United States.[2] The true cochineal has only a light powdery covering, while the form in the United States is provided with the heavy covering of cottony wax which has been described.

The true cochineal insect has had a most interesting history. Carried to many parts of the world and cultivated with extreme care, for many years the dried bodies of the females yielded a dye product of great importance in the commercial world. It was also supposed to be an important therapeutic agent.

In A. von Humboldt's Political History of the Kingdom of New Spain, published in 1811, there is a most interesting account of the cochineal industry in southern Mexico. The author relates that there was every indication that the cultivation of the insect had been practiced for many centuries, undoubtedly, even antedating the invasion of the Toltec tribes. During the reign of the Aztec kings the industry was apparently much more important than at the time of Humboldt's observations. As early as 1592 laws were passed to prevent the adulteration of the product. In 1802 the exports through the port of Vera Cruz amounted to 3,368,557 pounds.

The greatest development of the cochineal industry occurred about 1876. The decline began at that time on account of the discovery

[1] Order Hemiptera, Family Coccidæ.

[2] The records from Florida and California in the Fernald Catalogue are probably due to importations.

of aniline dyes. For several years the commercial cochineal crop of the world amounted to more than 7,000,000 pounds. Although the amount produced now is very much smaller, it seems to be more or less constant. In 1909, the last year for which statistics are available, the United States imported 102,000 pounds of a value of $33,875. Practically all of this supply is obtained, either directly or indirectly, from the Canary Islands. The average annual importation into the United States for seven years ending with 1909 was 130,000 pounds.

Cochineal is now used as a coloring matter for fine fabrics, certain kinds of ink, and confectionery. It is also used as a coloring medium for solutions and emulsions, being found practically in every drug store in the country. For many years it was used more or less regularly as an anodyne, but this use has been largely discontinued.

The cottony cochineal insect occurs practically throughout the cactus region in the United States. It has been found to be abundant as far north as Young County, Tex. It is attacked by a large number of predaceous insects. These tend greatly to hold the cochineal insect in check. Otherwise it would be a pest of prime importance on Opuntia plantations. As it is, it not infrequently becomes so abundant as to destroy portions of the plants and, on occasions, even as far north as central Texas, it has been found that entire plants have been destroyed.

ENEMIES.

The insect enemies of the cottony cochineal insect, so far as known, consist of eight species of Coleoptera and three of Lepidoptera, as follows:

COLEOPTERA.

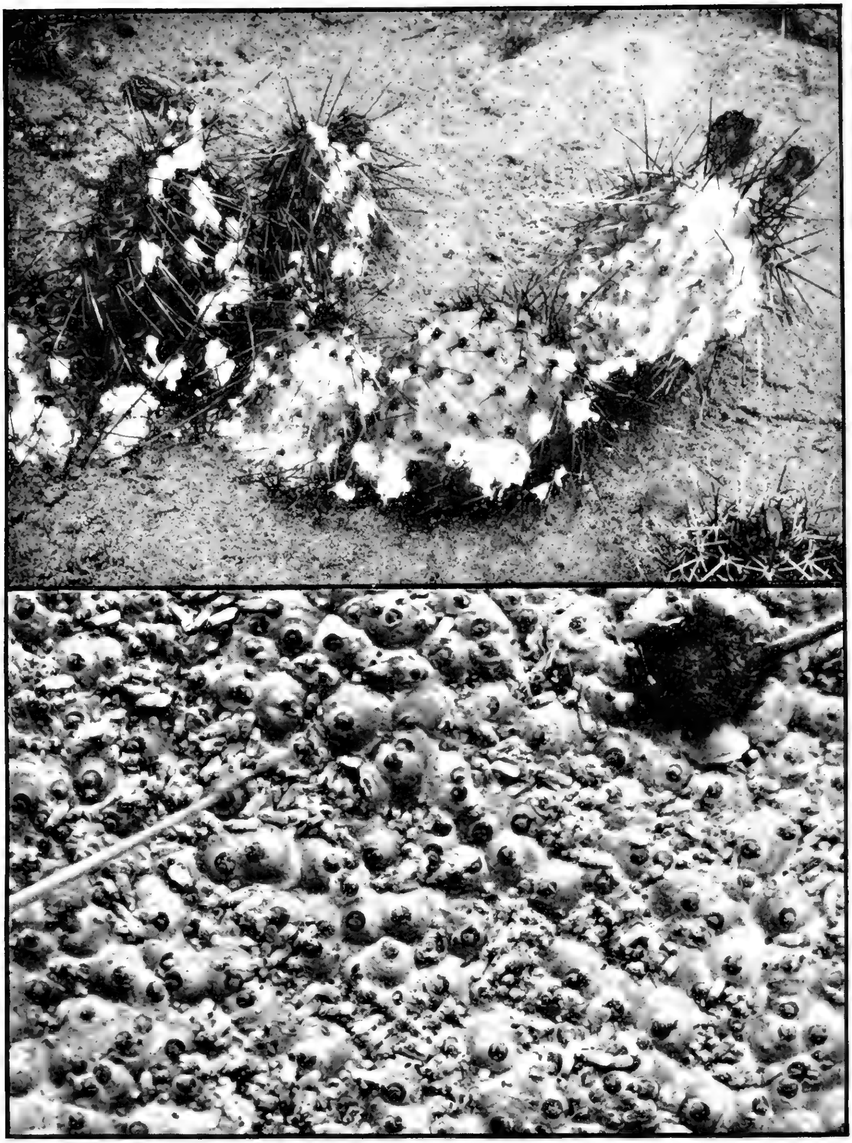
Exochomus latiusculus Casey; *Exochomus marginipennis* Le Conte; *Cycloneda munda* Say; *Chilocorus cacti* Linnæus; *Hyperaspis trifurcata* Schaeffer; *Hyperaspis cruenta* Le Conte; *Scymnus loewii* Mulsant; *Scymnus hornii* Gorham.

LEPIDOPTERA.

Lætilia coccidivora Comstock; *Zophodia dilatifasciella* Ragonot; *Saluria ardiferella* Hulst.

CONTROL.

Attention has been called to the fact that in the United States the insect enemies of the cottony cochineal insect prevent its reaching great numbers until the middle of summer. In artificial plantings at times it may be necessary to resort to remedial work. In such cases the best plan to follow will be to remove the masses on the joints by means of a very stiff brush or to burn them with a torch. In some cases spraying with kerosene emulsion or the lime-sulphur mixture might be followed, but the extensive secretion of the insect will interfere greatly with the application of any insecticides.



TWO IMPORTANT SCALE INSECTS OF PRICKLY PEAR.

Upper figure, the cottony cochineal insect, *Dactylopius confusus;* lower figure, *Diaspis echinocacti cacti.* Lower figure enlarged. (Original.)

In hothouses the use of a solution of whale-oil soap or of tobacco stems is recommended for this and other scale insects of cacti. Any preparation that may be used should be applied with considerable force by means of a spray pump in order to reach the insects in the crevices of the plants.

Minor Species Attacking the Joints Externally.

In addition to the species described in the preceding pages a considerable number of forms have been found which occasionally feed upon the joints. None of the other forms is at present known to be of any great economic importance, although they are likely to become abundant and injure the plants under local conditions at any time. The species more likely to do so are mentioned in the following paragraph.

Diaspis echinocacti cacti Comstock is a grayish scale insect, the females circular and the males oblong. It sometimes becomes so numerous as to cover entirely the surface of the joint. This condition is shown in an accompanying illustration. (Pl. V, lower figure.) In artificial plantings and in hothouses this species is of some importance. Under field conditions it rarely reaches excessive numbers. *Dactylopius tomentosus* Lamarck, which resembles the cottony cochineal insect but differs from that species by the fact that the separate individuals, instead of masses of several individuals, are covered by the cottony secretion, may be destroyed by the means recommended for the cottony cochineal insect. The white ant *Termes flavipes* Kollar feeds upon a great variety of cactus plants and has been observed to injure the joints thrown on the ground for growing a new crop. It sometimes constructs nests in the damaged joints. The scale insect *Eriococcus coccineus* Cockerell has been recorded from California. *Aphis medicaginis* Koch, a plant louse, apparently passes the winter on Opuntia in Texas. During the remainder of the year it is seldom found on Opuntia plants, and on the whole causes only very slight injury.

SPECIES ATTACKING THE JOINTS INTERNALLY.

Melitara junctolineella Hulst.[1]

Melitara junctolineella Hulst and the other species of the genus are true cactus insects. They may be recognized from the following brief description: Large indigo-blue (young) or conspicuously banded (last stage) larvæ living within the joints of Opuntia, cause large excavations and tumor-like swellings of the infested joints. The adult is a grayish moth of an expanse of 1½ inches.

The eggs of this species are very similar to those of *Melitara prodenialis* Walk. which are described on another page. They are deposited in exactly the same manner. The remarkable arrangement

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[1] Order Lepidoptera, family Pyralidæ.

is shown in one of the accompanying photographs. (Pl. VII, fig. 1.) The individual egg masses may contain as many as 30 eggs.

There seems to be only one brood each year. As soon as the larvæ hatch in the spring they begin feeding upon the surface of the joint. Within a few days they make their way to the inside and never appear upon the surface. The experience of all observers is that only one or two larvæ are ever found within a joint. This is remarkable in view of the fact that the eggs are deposited in such numbers. Apparently it is not a case of the young larvæ traveling from one joint to another, since frequently only one or two joints on a plant are found to be infested. Undoubtedly the larvæ are cannibalistic in habits, and this accounts partly for the fact that these isolated individuals are found; but there is also another factor to be considered. The work of the larvæ immediately causes a strong reaction on the part of the plant. A copious secretion of proliferous tissue is formed and larvæ have been frequently found completely engulfed in this formation. Undoubtedly the pressure frequently results in the destruction of the larvæ.

Although this species is an internal feeder, the indications of its work are more or less conspicuous. The joint soon takes on a yellowish appearance and the large swellings on both sides of the joints are common sights in the cactus country. The entire interior is destroyed and the proliferous growth causes the swellings which frequently result in the increase in the thickness of a joint by three or four fold. Strangely such swollen joints are sometimes found to contain no larvæ. The evidence of their work is always present. Pressure from the proliferous growth may have caused the death of the larvæ in such cases.

The effect upon the plant is generally to cause the death of the joint or joints which are infested. The injury is made greater by a number of scavengers, principally dipterous. As the larvæ frequently make their way through the stem from one joint to another, it is not uncommon for several joints to be killed outright. Of course the portion of the plant above the infested joints dies from lack of nutrition. After a time the wind causes the diseased branch to fall to the ground. In case the larvæ are killed by pressure the swelling subsides. The sides, however, do not unite and the joint remains deformed. Mr. J. D. Mitchell, who has made many careful observations on this species, believes that the partial healing of the injury follows when the exit is at the lowest part of the stem, and that the joint falls invariably when the exit is near the top and the softened excrement and proliferous tissue can not escape.

Although this insect is not extremely abundant in any locality where observations have been made, it is to be found throughout the cactus area. In some localities at least one plant in every clump has

some portion infested. The total damage done is consequently considerable.

DIVERSITY OF HABITS.

All of the Melitaras reared from cactus during the course of this investigation have been identified by Dr. H. G. Dyar as *Melitara junctolineella* Hulst. However, certain peculiarities in habits have been observed which lead to the suspicion that more than one form may occur. In the region south and east of San Antonio, Tex., the only form occurring makes no opening through the surface of the joint, but packs its excrement in the cavity made in the process of feeding. This form spins a cocoon on the joint or on the ground in case the joint has fallen, but this cocoon is not intermixed with sand or dirt. In the region from Kerrville, Tex., westward, a form occurs which invariably provides an orifice in the joint of the Opuntia through which the excrement is dropped to the ground. This gives a characteristic appearance of the joint which is easily recognized at a considerable distance. This form seems invariably to enter the soil for pupation, and a considerable amount of sand is intermixed with the cocoon spun for the protection of the pupa.

DESCRIPTION OF IMMATURE STAGES.

The Larva.[1]

Early stages whitish; subsequent stages up to the last deep indigo-blue; last stage, 30 to 50 mm. long, conspicuously banded. These bands are dark brown and occupy the posterior quarter of each segment. Head 2.5 mm. wide, dark brown; clypeus rather deeply emarginate, with light colored band at base. Anal plate almost semicircular in outline, yellow; feet yellow, crochets in ellipses; skin plainly wrinkled on dark annulations, less wrinkled on lighter portions; spiracles elliptical, one and one-half times as long as broad, deep black; thoracic legs light brown; hair very sparse, light yellowish, confined to head, sides, and underside.

The Pupa.

Incased in loose silken cocoon, sometimes intermixed with sand, 25 mm. long by 9 mm. wide, uniform mahogany brown, spiracles darker; head and thorax transversely rugose; anterior portion of abdominal segments very finely punctured; posterior portions more sparsely punctured and slightly wrinkled.

PARASITE.

A tachinid parasite of this species, *Phorocera comstocki* Williston, is common. It has been reared from material collected throughout the cactus area.

CONTROL.

The process of singeing the spines of prickly pear preparatory to feeding undoubtedly destroys many of the eggs of this species. In

[1] The larva described by Dr. Dyar as probably that of *M. junctolineella* (Proc. U. S. Nat. Mus., vol. 25, p. 396) evidently belongs to some other species.

experimental plantings the use of the gasoline torch in the spring and the burning of the joints that appear injured will keep the species in check.

Melitara dentata Grote.

Melitara dentata was described by Grote in 1876 from Colorado. In 1892 Prof. V. L. Kellogg published an account[1] of the transformations of the species in the leaves of *Opuntia missouriensis* taken in eastern Colorado. All stages were described and illustrated. The occurrence of blue and white larvæ, which we have observed frequently in the case of *Melitara junctolineella*, was noted by Prof. Kellogg.

The same species was collected by Mr. David Griffiths in Trinidad, Colo., in June, 1906. From this material a large number of parasites, *Chelonus laticinctus* Cresson (fig. 2), were reared.

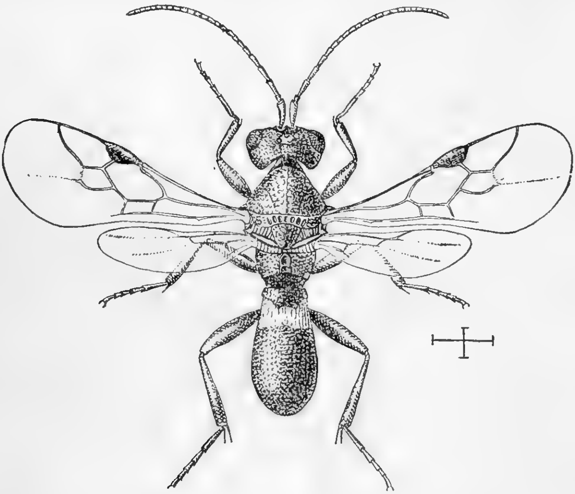

FIG. 2.—*Chelonus laticinctus*, a parasite of a cactus insect, *Melitara dentata*: Adult. Enlarged. (Original.)

Melitara prodenialis Walker.

The species *Melitara prodenialis* of Walker was described in 1863. In 1877 Miss Mary Treat sent cocoons from *Opuntia polyantha* collected at Green Cove Springs, Fla., to the Bureau of Entomology. In 1895 Mr. H. G. Hubbard published an interesting account of the oviposition of the species on *Opuntia vulgaris* at Crescent City, Fla., and also included an account of the habits of the larvæ. Previously Dr. J. B. Smith[2] had described briefly the method of placing the eggs on the plant. These few records constitute all that has ever been published concerning the species.

The notes on oviposition of this species and the habits of the larvæ, made by Mr. H. G. Hubbard, are as follows:

The eggs are laid at night, and the operation of depositing them has not been observed. It must, however, be a wonderfully interesting performance. The egg-stick * * * is 80 mm. long. The separate eggs are cylindrical and

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[1] Kans. Univ. Quarterly, vol. 1, pp. 39–41.
[2] Entomological News, vol. 3, p. 208, 1892.

measure 2 mm. in length by 7 mm. in width. The surface is beautifully reticulated with wavy raised lines anastomosing obliquely. The eggs are cemented together with a brownish glue which, under the pressure exerted upon the mass, is squeezed out at the sutures between each two eggs in the stick and hardens there, forming a ring or collar which always adheres to the egg beneath when two eggs in the stick are separated. It sometimes has the appearance of a circle of spinules, owing to the corrugations of the surface upon which it is moulded.

The young larvæ of *Melitara prodenialis*, on hatching from the eggs, feed for a time externally upon the bud-like leaves of Opuntia. When they become larger and stronger they cut through the silicious skin of the pads. The wounds made by them in the plant exude a gummy liquid, and a scab-like crust is formed. Under this the larvæ live in companies, large or small, according to the size of the plant, until they are about one-third grown. After this they burrow deeply into the substance of the succulent stems. The larvæ, as long as they live upon or near the exterior of the plant, are light brown in color, but after they burrow into the pulp and approach their full size, they attain a most beautiful dark-blue color. In pupating they form a loose cocoon of yellow silk, which is concealed somewhere about the Opuntia clump, usually under a prostrate pad.

There appear to be two broods produced during the year, since moths were found issuing in Florida in June and again in October.

Melitara fernaldialis Hulst.[1]

This species, which occurs in Arizona and New Mexico, has not been found breeding in Opuntia, but was found by Mr. Hubbard to infest the giant cactus, *Cereus giganteus*. In all probability it will be found to attack Opuntias in the region in which it occurs. In fact, in May Mr. F. C. Pratt discovered a larva which may have been of this species in *Opuntia engelmanni* at Tucson, Ariz. This larva discharged its excrement through an opening in the surface of the leaves exactly as does the form which occurs in the western portion of Texas. Apparently the same form was observed by Mr. Pratt at Albuquerque, N. Mex., in June. At Sante Fe, N. Mex., during the same month, about 30 per cent of the plants of *Opuntia arborescens* were more or less injured. Unfortunately, it was impossible to rear any of these larvæ. Our supposition that they were of the species *fernaldialis* is based upon the known range of that form and the fact that they appeared to be different from the Melitara larvæ observed in Texas.

Gerstæckeria porosa Le Conte.[2]

The presence of the weevil *Gerstæckeria porosa* Le Conte is readily shown by the occurrence of flat discolored areas about three-fourths inch in diameter on the surface of the joints. In the early stages of attack these areas are yellowish, but later become whitish. They cover the cavities excavated by the larvæ.

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[1] Order Lepidoptera, Family Pyralidæ.
[2] Order Coleoptera, Family Curculionidæ.

This species is distributed throughout the cactus region. It has been taken as far north as Denver, Colo., and as far south as San Diego, Tex. Its range extends into Arizona.

The winter is passed in the pupal state within the cells in the Opuntia joints. The adults issue from April to June. There appears to be only one brood during the season. The species is responsible for a large amount of disfiguration of the cactus joints, but as the cells are largely superficial the growth of the plant is not seriously affected. In fact, in no cases observed have the joints been found to be destroyed primarily by the insects. In some cases, however, the cells attract scavengers of various species, which increase the diseased area and may cause the destruction of the joints. The adults appear to feed by scraping the epidermis from the sides of the joint.

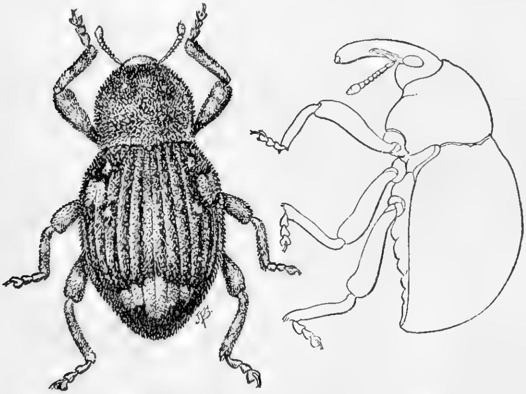


FIG. 3.—A cactus weevil, *Gerstæckeria nobilis*: Adult. Enlarged. (Original.)

Gerstæckeria nobilis Le Conte.

The work of *Gerstæckeria nobilis* Le Conte (fig. 3) is precisely like that of the preceding species except that the cells containing the immature stages are located on the margins of the joints. In these localities a hard black exudation frequently forms, and this interferes with the development of new growth. For this reason it is more important than the preceding species, although it is of less extensive distribution. Our records include many localities in Texas from Dallas to Corpus Christi. It does not appear, however, to extend far to the west, Hondo being the westernmost locality in our records.

Gerstæckeria clathrata Le Conte.

Gerstæckeria clathrata Le Conte works exclusively on *Opuntia leptocaulis*, so far as known, although it may rarely infest allied species. Its work in the plants is similar to that of the other species. It is partial to the new growth, which is often killed. Although thus more destructive than the preceding forms, it is of less economic importance on account of the uselessness of its host. It is recorded from Colorado to Brownsville, Tex., and westward to Arizona.

A fourth species, *G. hubbardi* Le Conte, was reared from *Opuntia vulgaris* in Florida by Mr. H. G. Hubbard. It appeared to follow the work of *Melitara prodenialis* Walker.

The four species described are true cactus insects, being dependent upon the plant for food and places for breeding. Although only four species have been discovered breeding in cactus, it is likely that upon investigation other species of the genus will be found to injure it. The genus contains 22 species, of which 11 are found in the United States and the remainder in Mexico.

It is doubtful whether it will ever be necessary to resort to control measures in the case of any of the species of Gerstæckeria. If control should become necessary, it would be extremely difficult on account of the fact that the immature stages are passed beneath the surface of the joint. No remedy except the removal of the infested joints can be suggested.

Marmara opuntiella Busck.[1]

The tineid moth, *Marmara opuntiella* Busck (fig. 4), deposits its eggs just beneath the epidermis of the leaves of Opuntia. The first

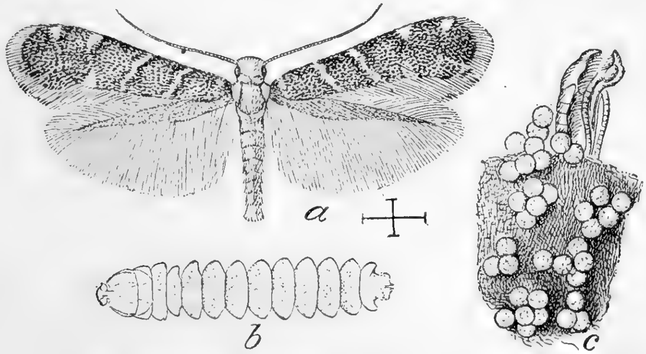


FIG. 4.—A cactus insect, *Marmara opuntiella*: *a*, Adult; *b*, larva; *c*, eggs and pupal case. Enlarged. (Original.)

indication of injury is a slight elevation of the epidermis above the gallery which the larvæ have begun to excavate. The first attack (Pl. VI) is generally near the base of the joint. Later the epidermis above the galleries becomes white and the galleries may cover the entire surface of the joint. This is certain to be the case where several eggs are deposited in one joint. A gummy exudation appears and the whole surface of the joint becomes covered with a yellowish secretion that conceals the mines. The larvæ work immediately beneath the epidermis and never penetrate the interior of the joint. On this account they have little effect upon the growth of the plant. Only on rare occasions when the attack has been directed against the new growth does the joint fall to the ground. The species is widely distributed in Texas, having been taken from New Braunfels southward to Brownsville.

[1] Order Lepidoptera, Family Tineidæ.

The only cases in which it will be necessary to combat this insect will be those in which the new growth of the plants is affected. The only course to follow is to remove these joints and burn them.

SPECIES INJURING THE BLOOMS.

In the category of species injuring the blooms there is only one that is of importance. This is *Trichochrous* (*Pristoscelis*) *texanus* Le Conte. It is a slender beetle, 3 mm. in length, uniformly olivaceous above, highly polished, with reddish legs, the upper surface of the body covered with rather dense growth of short whitish hairs. It has been collected at southwestern Texas and in New Mexico. At Albuquerque, in the latter State, on June 16, Mr. F. C. Pratt found it in such abundance that no blooms without indications of injury were noticed. The great majority of the plants had been fed upon to such an extent that fruiting had ceased. As many as 153 beetles were found in a single bloom. No larvæ could be found in the vicinity. It is possible that this species is not at all peculiar to cactus, but is to be found in blooms of various kinds. There was a remarkable absence of flowers on all plants except the Opuntias growing at Albuquerque at the time to which reference has been made. This may account for the concentration of the insects in the blooms of the Opuntias and for the damage accomplished. No similar cases had been observed in the numerous observations that had been made in Texas.

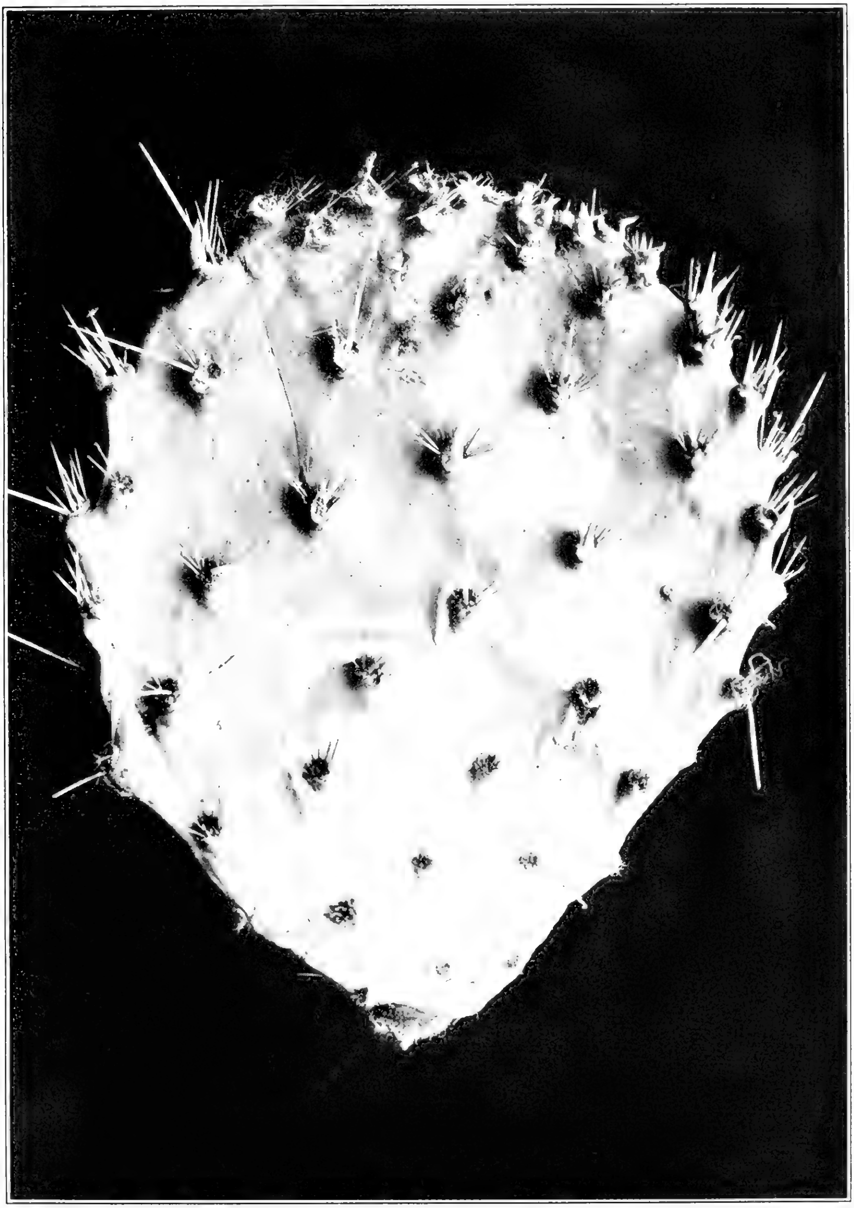
Euphoria kernii Haldeman[1] is a very common beetle in cactus blooms in Texas. It is a robust species of very variable color. Some specimens are pure black and all gradations between this form and individuals in which the ground color is yellow, but covered with narrow black stripes, are to be found. The species seems to feed upon the columns and anthers more than upon the petals. Even where it is so abundant that several individuals are to be found in every bloom no special injury to the plants has been detected. On this account the species is included in the list at the end of this bulletin as one which has no other association with the cactus plant than that it frequents the bloom.

SPECIES INJURING THE FRUIT.

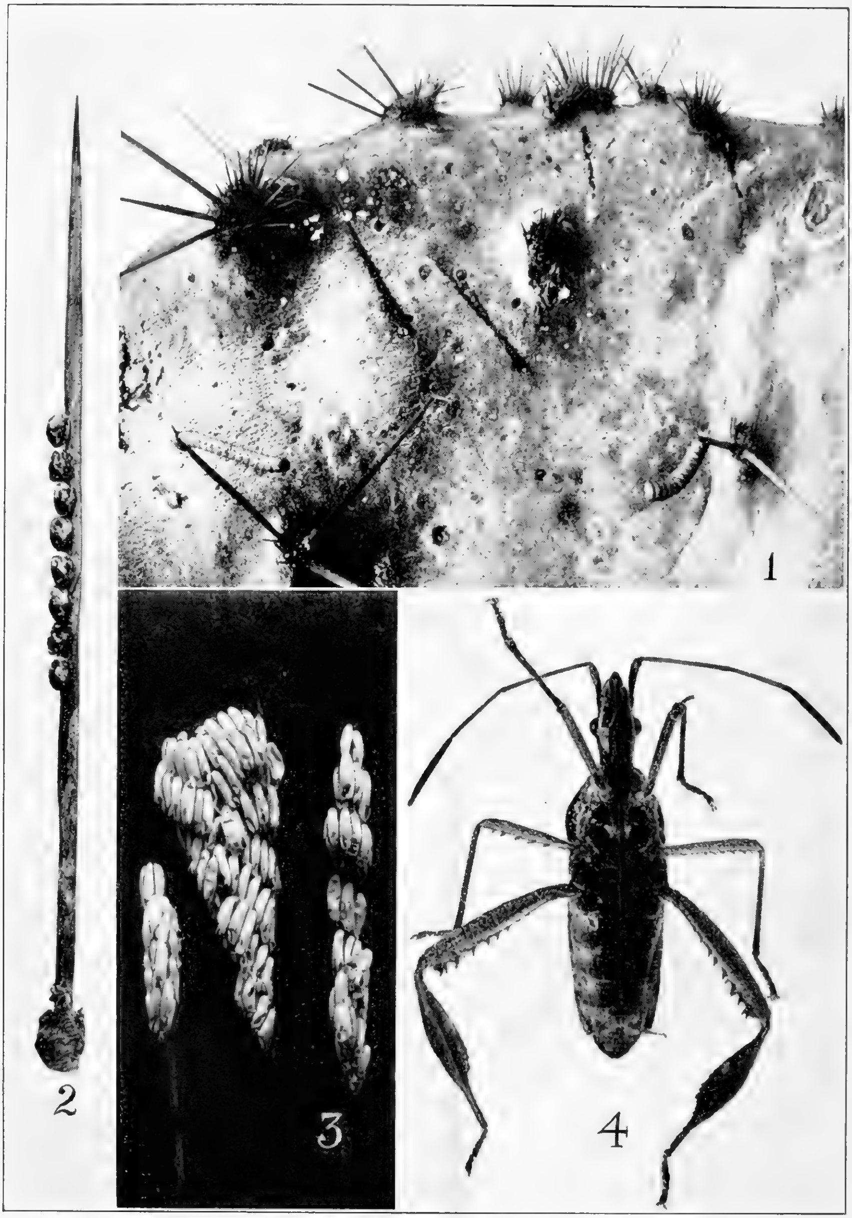
Narnia pallidicornis Stål.

Of the species that injure the fruit, by far the most important are the bugs of the genus Narnia, the most common being *N. pallidicornis* Stål.[2] The species can be recognized readily. (Pl. VII, fig. 4.) It is of a brownish-yellow color, about 15 mm. in length. The posterior femora are lengthened, very robust, and covered with heavy black

[1] Order Coleoptera, Family Scarabæidæ. [2] Order Hemiptera, Family Coreidæ.



JOINT OF PRICKLY PEAR, SHOWING WORK OF MARMARA OPUNTIELLA. (ORIGINAL.)



STUDIES OF CACTUS INSECTS.

Fig. 1.—Eggs of *Melitara junctolineella* on spines of Opuntia. Fig. 2.—Eggs of *Chelinidea vittigera* on spine of Opuntia. Fig. 3.—Eggs of *Copestylum marginatum* on Opuntia spines. Fig. 4.—*Narnia pallidicornis*. (Original.)

spines. The posterior tibiæ are expanded just beyond the middle into fanlike dilations.

This insect is essentially an enemy of the fruit of the Opuntias. Although it has been observed very commonly in Texas, it has never been found to injure the joints. Like the bugs of the genus Chelinidea, it and its immediate relatives are gregarious in their habits. The range extends from Mineral Wells, Tex., southward to Brownsville and westward to El Paso.

DESCRIPTIVE.

THE EGG.

Egg.—Length, 1.5 mm.; width, 1 mm. Dark brown in color, cylindrical, sharply truncate at both ends, surface very finely roughened. Toward the upper end the lid appears as a raised spot with a light ring. Placed with ends contiguous on cactus spines, from 12 to 25 on a spine, sometimes several strings alongside of each other on the same spine. Length of egg stage, about 27 days.

THE NYMPHAL STAGES.

First instar.—When first hatched, the bugs are slightly less than 4 mm. in length, orange in color, but soon change to a reddish hue. Antennæ brown, 4-jointed, club and first joint equal, second joint slightly longer, basal joint barely one-half the length of the others; all joints covered with hairs, those on the club shorter. Legs reddish, hairy; tarsi dark brown, having shorter hairs. Head reddish; eyes brown; pronotum reddish and armed with a pair of erect spines; abdomen reddish, with four pairs of red spines located on the first, second, fourth, and fifth segments. Margins of abdomen with a row of six erect spines, those at base being longest. Each spine terminates in a short, black, motile bristle. The third and fourth pairs of spines are located on a raised callosity. Length of this stage, 7 days.

Second instar.—Length, 5 mm. Antennæ lighter in color than in previous stage, except club, which is dark brown; front and middle pairs of legs yellow, posterior pair darker, dilations on tibiæ now appearing; terminal tarsal joints bearing claw, which is dark brown; head, thorax, and pronotum dark brown; front of head yellow, abdomen reddish. Spines as in first stage, the pronotal spine being twice the length of the others. Length of this stage, 7 days.

Third instar.—Length, 6 mm. General color of body brown; antennæ, except club, and front and middle pairs of legs yellow; club of antennæ and posterior legs brown, except joints and tarsi, which are yellow; callosities on pronotum and margins of abdomen whitish, those on abdomen black. An additional pair of spines appears on thorax. Length of this stage, 13 days.

Fourth instar.—Length, 9 mm. Antennæ as in third stage. General color dull velvety black and speckled as if dusted with white powder; sparsely covered with shiny, white hairs, those on posterior legs longer and more dense; abdomen reddish beneath. Length of this stage, five days.

Fifth instar.—Length, 15 mm. Same coloration as preceding stage, hairs apparently more dense, pronotal spines yellow at base. Thorax well defined. Wing-pads have now appeared, extending over pronotum, yellow. Abdomen yellow, beneath black. Length of this stage, 7 days.

As has been stated, this is an important enemy of the Opuntia plant where the fruits are desired for food. In cactus plantations, however, where the plants are reproduced by cuttings, it is of comparatively little importance. On account of its gregarious habits and its location on the parts of the plant easily reached by a gasoline torch, its control is not a difficult matter.

There are three other species of Narnia which feed upon the fruit of Opuntia and related plants. After *pallidicornis*, the most common species is *femorata*, which is as widely distributed in Texas as that species and extends its range as far westward as Los Angeles, Cal. It has also been taken in Mexico at Aguascalientes, Victoria, and Durango. In general appearance it resembles *pallidicornis* very closely, but is somewhat larger. *N. pallidicornis* has the dilation of the hind tibia narrower, lanceolate shaped, and the inner part of the dilation broadest behind the middle.

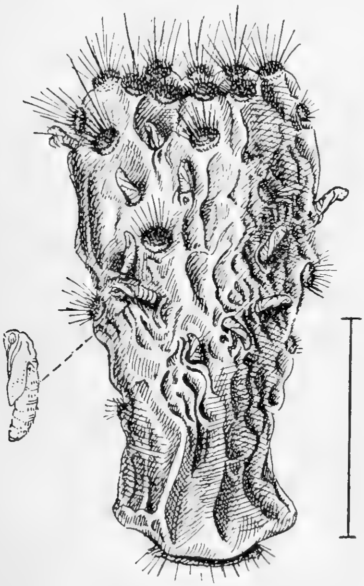


FIG. 5.—Opuntia fruit with puparia of *Asphondylia opuntiæ*. Enlarged. (Original.)

The remaining species of the genus which we have observed on cactus are *inornata* and *snowi*. The former has been taken in California and Mexico only, while we have only a single record of the latter species, at Albuquerque, N. Mex., in April.

Asphondylia opuntiæ Felt.[1]

Asphondylia opuntiæ Felt ranks next in importance to the Narnia bugs so far as injury to the fruits of Opuntia is concerned. It is not restricted, however, to the fruits, but sometimes infests the margins of the joints. Its presence is first detected by a yellowish coloration of the fruit or joint and later by the protruding puparia in close groups of sometimes as many as 10 individuals (fig. 5).

This species has a wide range. Specimens have been taken at many points in Texas and southward to San Luis Potosi, Mex., and westward to Los Angeles, Cal. There are evidently several generations in the season, the first adults appearing in southern Texas in March.

Especially in California this species is extremely abundant. On this account it is fortunate that its injury primarily affects the fruit and does not interfere seriously with the growth of the plant. It

[1] Order Diptera, Family Cecidomyiidæ.

can not interfere seriously with the production of forage. It is of greatest importance in Mexico, where the fruit of the Opuntia plant is a very common article of diet for the natives.

Instances of curious deformations of the plant result from the work of this fly. The infested fruit, instead of developing as such, is transformed into a very short joint, which gives rise to a larger or nearly normal joint. The remarkable change in the appearance of the plant caused in this way is sometimes very conspicuous. The result of the work of the same or a similar species was described as an abnormal fruit of *Opuntia ficus-indica* from Caracas by A. Ernst.[1]

Three additional species of Cecidomyiidæ have been rearèd from Opuntia. They are included in the list at the end of this bulletin, but need not be considered in this connection on account of their very rare appearance.

Cornifrons elautalis Grote.[2]

Cornifrons elautalis Grote is a small grayish moth infesting the green fruits of Opuntia. It was first collected by Mr. J. D. Mitchell in May, 1908, at Hondo, Tex. Later it was taken at Tucson, Ariz., but on the whole seems to be of rare occurrence. The larvæ bore into the fruit to a depth of 1 inch and eject a reddish-colored excrement on the crown of the fruit, causing its death. At Tucson, Ariz., in May, Mr. F. C. Pratt noticed that many fruits were injured by these larvæ. On some plants practically all of the fruits were injured, and it was found that the larvæ traveled from one fruit to another. In that vicinity fully 10 per cent of the fruits were injured.

The larvæ are generally to be found just beneath the corolla, which remains on the crown longer than when the fruit is uninjured. When the corolla falls the larvæ web over the orifice made in the fruit, and the protection is augmented by the addition of the reddish excrement. They also occur in the blooms, but leave them as soon as the flower parts become dry.

It is evident that eggs are generally deposited in the blooms, although this is not by any means invariable. Many fruits were observed in which entry had been gained from the side.

The larvæ are blackish, with a shining black head and narrow, lateral crimson bands.

Allorhina mutabilis Gory.[3]

Mr. E. A. Schwarz informs us that *Allorhina mutabilis* Gory is a common enemy of the fruit of Cereus in Arizona. It is well known for its damage to fruits of various kinds.

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[1] Nature, November 23, 1882, p. 77.
[2] Order Lepidoptera, Family Pyralidæ.
[3] Order Coleoptera, Family Scarabæidæ.

Sixeonotus luteiceps Reuter.[1]

The adults of *Sixeonotus luteiceps* Reuter are 3 mm. long, with dark steel-blue wing covers and red head and thorax. The nymphs are bright scarlet. The range of the species is in southwestern Texas. It is not a true cactus insect, although frequently found upon the plant. It seems to prefer yuccas. On these plants it has frequently been observed in great numbers, while Opuntia growing in the immediate vicinity remained uninjured. When cactus plants are attacked the preference seems to be for the ornamental forms of the "pitallo" group. When in large numbers it disfigures these plants considerably, and sometimes causes their death. The first indication of injury is a yellowish discoloration, while the surface is covered by numerous black specks of excrement.

Polistes spp.[2]

Two species of wasps of the genius Polistes, namely, *rubiginosus* and *texanus*, have been taken commonly in Texas, and one, *flavus*, was taken on Cereus in Arizona by Mr. H. G. Hubbard. The adults of these species are found everywhere on the fruit of Opuntia and other cacti. They cut open the partially ripened fruit with their mandibles and feed upon the juices that exude. They are of very little importance from the standpoint of the cultivation of the plant.

Liotropis contaminatus Uhler.[3]

The species *Liotropis contaminatus* Uhler, recorded by Prof. H. Osborn[4] on fruit of *Opuntia fulgida* near Tucson, Ariz., occurs also at El Paso, Tex., and in the Inyo Mountains, Cal., at the latter locality at an elevation of 7,000 to 9,000 feet.

Dytopasta yumaella Kearfott.

Reared from Opuntia fruit collected at Hondo, Tex., by Mr. J. D. Mitchell in June. Also taken in Arizona.

Ozamia lucidalis Walker.

Observed at Victoria, Austin, San Antonio, and Hondo, Tex. Larva moves from fruit to fruit, thus destroying sometimes as many as five. Cocoon whitish, silky, unmixed with foreign matter, placed on side of fruit. Evidently widespread, but never abundant.

Platynota rostrana Walker.

Reared from Opuntia fruit collected at Brownsville, Tex., in May by Mr. J. D. Mitchell. This is the only record we have obtained.

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[1] Order Hemiptera, Family Capsidæ.

[2] Order Hymenoptera, Family Vespidæ.

[3] Order Hemiptera, Family Pentatomidæ.

[4] Ent. News, vol. 20, p. 177, 1906.

SCAVENGERS.

In the list of insects found associated with the cactus plant at the end of this bulletin we have included 73 species in the category of scavengers. Many of these species feed only upon the joints when these have been killed by other insects or when they are blown to the ground. A considerable number of the scavengers, however, breed in the living joints, obtaining entrance through the mines of Moneilema, Melitara, and other forms. The diseased condition caused primarily by the original inhabitant of the joint is increased by the work of such scavengers. They are therefore incidentally injurers of the plant. The cavities they inhabit become infested by various fungi and bacteria and the diseased area increases in size when, without the intervention of these scavengers, the plant would be able to heal the wound.

Copestylum marginatum Say.[1]

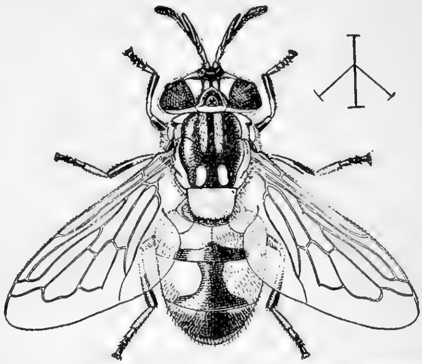

FIG. 6.—A cactus insect, *Copestylum marginatum:* Adult. Enlarged. (Original.)

The most common of the scavengers which increase the effects of the attack of other insects is *Copestylum marginatum* Say (fig. 6). The adults of this fly are to be found about the cactus plant from March to October. They are also taken commonly in the blooms of a long list of plants found in the cactus region. Undoubtedly they breed in decaying vegetation of all kinds, but one of the most important breeding places is the joints of cactus that have been injured by Melitara, Moneilema, Gerstæckeria, and other forms. Very soon the interior of the joint becomes filled with a dark. malodorous liquid, which undoubtedly causes the rapid decay of the plant tissues.

The adult fly deposits its eggs on the spines in large masses. (Pl. VII, fig. 3.)

The larva of this species measures 20 mm. by 4 mm.; the tail is 1 mm. in length. It is shining, its skin wrinkled. In color it is white, the tail dark brown. Each ventral segment has two almost contiguous oval areas of very short, stout, brownish spines, and there are similar spines on the head segment. The puparium is 10 mm. by 4 mm., calcareous, its surface dirty whitish, covered with particles of sand. There are many annulations of spinose areas, more distinct beneath.

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[1] Order Diptera, Family Syrphidæ.

In the same category as the preceding species are four species of the closely allied genus Volucella, namely, *esuriens*, *avida*, *pusilla*, and *fasciata*. They have been found numerously in practically all localities where cactus insects have been collected, occurring frequently with *Copestylum marginatum* Say and other species.

Hermetia spp.[1]

Almost equally important are two species of Hermetia, namely, *chrysopila* (fig. 7) and *hunteri*. The former is much more abundant and occurs from Dallas, Tex., southward to San Antonio and westward as far as Los Angeles, Cal.

The larvæ of *Hermetia chrysopila* Loew measure 35 mm. by 10 mm., the tail 2 mm. The integument is very tough and leathery, dark brown, its surface densely and evenly punctured, with indistinct transverse rows of callosities near the posterior third. The head is deeply, longitudinally impressed below, with two longitudinal ridges above.

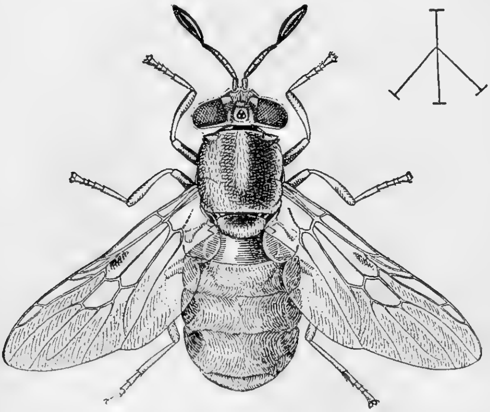

FIG. 7.—A cactus insect, *Hermetia chrysopila:* Adult. Enlarged. (Original.)

This species has been collected from April until September and has been observed depositing eggs in the empty cells of Gerstæckeria as well as in the openings made by Melitara and other species. It is not at all restricted to cactus, but undoubtedly breeds in decaying vegetable matter of any description. The adults are found in flowers of many species as well as in those of Opuntia.

The most remarkable observation made on this species relates to the longevity of the larva. In May, 1909, a number of specimens which appeared to be nearly full grown were taken at Hondo, Tex., by Mr. J. D. Mitchell. They were placed in breeding cages, from which adults appeared irregularly between July 17 and August 19. Some of the larvæ, however, did not yield adults. They remained motionless in the bottom of the cages. Whenever a new supply of food in the form of decaying cactus was introduced they began feeding, but as soon as the food dried they became quiescent. After it was observed that they were of rather remarkable longevity no food was introduced for over a year. The larvæ lived for more than 15 months without food and developed readily later when food was sup-

[1] Order Diptera, Family Stratiomyiidæ.

plied. The very leathery integument seems to protect the insect against desiccation, and in other ways the larva has evidently adapted itself to long periods of waiting for favorable food, which, in the arid regions, depends upon the infrequent rains.

Stictomyia longicornis Bigot.[1]

The *Stictomyia longicornis* of Bigot is an exceedingly common insect throughout the cactus area. The adults are small flies with spotted wings. The wings are bent downward at about the middle, so that the name of "droop-winged fly" seems appropriate. (See fig. 8.) The larvæ occur along with Copestylum, Volucella, and Hermetia in any part of the cactus plant that may be injured. They also infest wounds made by knives when cuttings are removed for planting.

The remaining insects listed as scavengers are of less general occurrence than the species mentioned in the preceding pages and no special notes have been made upon them.

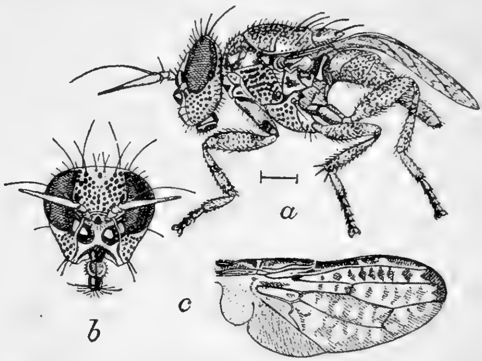

FIG. 8.—A cactus insect, *Stictomyia longicornis*: *a* Adult in profile; *b*, head; *c*, wing. Enlarged. (Original.)

LIST OF THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.

The following list deals primarily with the species attacking or associated with the genus Opuntia and includes all published records of previous investigators. Many forms not restricted to Opuntia are included because, as Mr. Schwarz has pointed out, the insects of that plant are interchangeable with those of other plants of the family Cactaceæ. For this reason we have included all of the records of species taken on *Cereus giganteus* in Arizona by Mr. H. G. Hubbard.[2] The names of such species are preceded by an asterisk. We have also included references to some exotic species, principally from Mexico.

The published records of cactus insects, including those of Mr. Hubbard, deal with 105 species. The present list includes 324 species. These are divided, for convenience, into the following groups: Injurious 92, parasitic or predaceous 28, scavengers 73, visitors of flowers 40, incidental 91.

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[1] Order Diptera, Family Ortalidæ.

[2] Except *Platydema inquilinum* Linell, which was taken in a rat's nest.

The determinations in all cases have been made by the recognized authorities in the different groups. We are indebted to the following entomologists for assistance in this connection: E. A. Schwarz, H. G. Dyar, W. M. Wheeler, Otto Heidemann, W. D. Pierce, J. C. Crawford, and S. A. Rohwer. Mr. Schwarz also rendered most valuable aid in making suggestions throughout the course of the work and in reading the manuscript and proofs.

We are especially indebted to Prof. T. D. A. Cockerell for furnishing complete lists of Opuntia bees and for making many suggestions about the portion of the list dealing with the Coccidæ.

SPECIES WHICH INJURE THE PLANT.

ARACHNIDA.

Tetranychus opuntiæ Banks. Reported by Mr. David Griffiths as injurious, but not taken in present investigations.

ISOPTERA.

Termes flavipes Kollar. Sabinal, Tex., September (F. C. Pratt); Falfurrias and Hondo, Tex. (J. D. Mitchell).

Attacks young Opuntia plants, also Cereus; frequently nests in decaying Opuntia and constructs covered galleries on joints.

HEMIPTERA.

Liotropis contaminatus Uhler. Tucson, Ariz.; El Paso, Tex. (H. F. Osborn).
Feeding on fruit of *Opuntia fulgida*.

Chelinidea tabulata Burmeister. Durango, Aguascalientes, and Victoria, Mex.; Tucson, Ariz.; Brewster County, Devils River, Oakville, Victoria, Austin, Hondo, and San Antonio, Tex. Throughout the season.
Feeds on joints.

Chelinidea vittigera Uhler. Colorado, Abilene, San Antonio, Knickerbocker, Trinity, Cotulla, Tivoli, Boerne, Encinal, Victoria, San Diego, Kerrville, Dallas, Oakville, Chisos Mountains, Mineral Wells, Hallettsville, Sabinal, Hondo, Falfurrias, Laredo, Fredericksburg, El Paso, and Austin, Tex. Throughout the season.
Feeds on joints.

Chelinidea sp. Tucson, Ariz., May (F. C. Pratt).
Feeding on joints of *Opuntia fulgida*.

Largus succinctus Linnæus. San Antonio, Tex., July (F. C. Pratt).
Feeding on joints of *Opuntia arborescens*.

Lopidea cuneata Van Duzee. Los Angeles, Cal., June (F. C. Pratt).
Feeds on joints of Opuntia.

Oncerometopus nigriclavus Reuter. Kerrville, Tex., August (F. C. Pratt); D'Hanis, Tex., April (J. D. Mitchell).
Feeding on joints of Opuntia.

Hadronema robusta Uhler. San Antonio, Tex., June (J. C. Crawford).
Feeding on joints of Opuntia.

Stylopidea picta Uhler MS. Victoria and D'Hanis, Tex., April (J. D. Mitchell); San Antonio, Tex., April (J. C. Crawford); Hondo, Austin, and Corpus Christi, Tex., May (F. C. Pratt); Brownsville, Tex., February (C. R. Jones and F. C. Pratt); Beeville, Tex. (E. A. Schwarz).

Feeds on joints.

Sixeonotus luteiceps Reuter. Hondo, Tex., May (J. D. Mitchell); Brownsville, Tex., March (C. R. Jones and F. C. Pratt).

Feeds on joints; especially partial to *Echinocereus* spp.; also taken on yucca and other plants.

Macrotylus verticalis Uhler (?). Los Angeles, Cal., June (F. C. Pratt).

Feeds on joints of Opuntia.

Corythuca decens Stål. Aguascalientes, Mex., December (F. C. Pratt).

On Opuntia.

Tucson, Ariz., June (J. W. Toumey).

Feeding on Opuntia joints.

Proarno valvata Uhler. Albuquerque, N. Mex., May (F. C. Pratt).

Apparently feeding on Opuntia joints.

Narnia femorata Stål. Taken at the following localities in Texas throughout the season: Mineral Wells (C. R. Jones); D'Hanis, Cotulla, Corpus Christi, Victoria, and Hebbronville (J. D. Mitchell); Hondo, Zavalla County, Sabinal, San Antonio, Kerrville, El Paso, and Llano (F. C. Pratt); also taken at Los Angeles, Cal., and Tucson, Ariz. (F. C. Pratt), and at Aguascalientes, Victoria, and Durango, Mex. (F. C. Bishopp).

Feeds on fruit of Opuntia and on Cereus; very destructive.

* *Dendrocoris contaminatus* Uhler, Tucson, Ariz.

Narnia pallidicornis Stål. Taken in Texas at localities below: Cotulla, Kerrville, El Paso, Sabinal, Austin (F. C. Pratt); Alice, Hondo, San Antonio, D'Hanis, Hebbronville, San Diego, Victoria, Encinal, and Oakville (J. D. Mitchell); Mineral Wells (C. R. Jones).

Occurs throughout the season; very destructive to fruits.

Narnia inornata Distant. Los Angeles, Cal., May (F. C. Pratt); Durango, Mex., November (F. C. Bishopp).

Feeds on joints.

Narnia snowi Van Duzee. Albuquerque, N. Mex., April (F. C. Pratt).

Feeds on joints.

Platypedia putnami Uhler. Albuquerque, N. Mex., June (F. C. Pratt).

Feeds on Opuntia joints.

Platymetopius fuscifrons Van Duzee. D'Hanis, Tex., April (J. D. Mitchell).

Feeds on joints.

Dictyobia permutata Uhler. Corpus Christi, Tex. (F. C. Pratt and A. C. Morgan).

Feeds on joints.

Aphis medicaginis Koch (det. C. E. Sanborn). Tucson, Ariz., May (F. C. Pratt); Hackberry, Ariz. (D. Griffiths); Dallas, Tex. (F. C. Pratt).

On Opuntia. Mr. Sanborn informs us that in Texas the species probably passes the winter on Opuntia.

Margarodes sp. (?). Montserrat, W. I. (C. V. Riley). According to Prof. Cockerell (in litt.) the species is undoubtedly *M. formicarum* (Guild.).

On Cereus roots.

Eriococcus coccineus Cockerell San Bernardino, Cal., September; also from greenhouse in Nebraska.

On joints.

Dactylopius confusus Cockerell. (Cottony cochineal insect.) Throughout the cactus region from Graham County, Ariz., southward, Texas, Florida, and California.

Feeds on joints of all species of Opuntia.

Also present in hothouses throughout the country.

Dactylopius (*Coccus*) near *confusus*. Barbados, W. I., May (D. D. Morris).

Dactylopius coccus Costa. (Cochineal insect.) Recorded from California and Florida, but probably introduced. Introduced in West Indies, Canaries, India, Peru, Spain, and other Mediterranean countries.

Dactylopius tomentosus Lamarck. Guanajuato, Mex., July (T. D. A. Cockerell); New Mexico; Arizona.

On *Opuntia fulgida* joints.

Dactylopius (*Coccus*) sp. Cape Town, South Africa (A. M. Cooper).

On *Opuntia polyantha*.

Dactylopius (*Coccus*) sp. Colorado Desert, Cal., January (D. W. Coquillett). San Bernardino, Cal.

Pseudococcus virgatus Cockerell. Brownsville, Tex.

On "Jacobo" cactus. (See also Cockerell, Can. Ent., 1895, p. 259.)

Pseudococcus obscurus Essig. California.

On roots of Opuntia.

Pseudococcus longispinus Targioni-Tozzetti (Syn.: *Dactylopius longifilis* Comstock).

(See Lintner, 2d N. Y. Report, p. 56.)

On prickly pear at Waterbury, Conn.

Pseudococcus sp. Mesilla Park, N. Mex., April (D. Griffiths).

On joints of *Opuntia cycloides*.

Ripersia sp.

On roots of cactus.

Diaspis cacti Comstock. Arizona and New Mexico.

On *Opuntia fulgida*, *O. arborescens*, and *O. engelmanni*.

Diaspis cacti opunticola Newstead. Demarara.

Diaspis echinocacti Bouché. According to Mrs. Fernald, Europe, India, Algeria, Porto Rico, Mexico, New Mexico, New York.

On *Opuntia ficus-indica*, *Echinocactus ottonis*, and *E. tenuispinus*, etc.

Diaspis echinocacti cacti Comstock. Laredo, Tex., March, on *Opuntia leptocaulis* and *O. lindheimeri* (F. C Pratt); San Antonio, Tex. (J. D. Mitchell); Arizona and New Mexico, on *O. fulgida*, *O. arborescens*, and *O. engelmanni* (T. D. A. Cockerell). According to Mrs. Fernald, Massachusetts and New York (greenhouses), Iowa, Arizona, New Mexico, Brazil, India, Mauritius, on Cactus, *Cereus giganteus*, *C. macrogonus*, *Echinocactus* sp.

Diaspis echinocacti opuntiæ Cockerell. Kingston, Jamaica (T. D. A. Cockerell); Sierra Blanca, Tex., on *Opuntia arborescens* (C. H. T. Townsend); Demarara, Texas, Mexico, on *O. arborescens* and *O. elongata*.

Pseudoparlatoria parlatorioides Comstock. Frontera, Mex. (C. H. T. Townsend).

Lepidosaphes (*Opuntiaspis*) *philococcus* Cockerell. On Opuntia in Mexico, according to T. D. A. Cockerell in litt.

COLEOPTERA.

Trichochrous (*Pristoscelis*) *texanus* Le Conte. Albuquerque, N. Mex., June, Zavalla County, Tex. (F. C. Pratt); D'Hanis and Brownsville, Tex. (J. D. Mitchell).

Occurs in great numbers in blooms, which are sometimes considerably injured.

Allorhina mutabilis Gory. According to Mr. E. A. Schwarz feeds on fruit of Cereus.

Moneilema ulkei Horn. Cotulla, Falfurrias, and Brownsville, Tex. (J. D. Mitchell); Sabinal, Tex. (F. C. Pratt); Oakville, Tex. (F. C. Bishopp).

Larvæ in roots; adults feed on joints.

Moneilema variolare Thomson. Mexico (Dugès).

Breeds in "Cactus Opuntia."

Moneilema annulatum Say.

On Opuntia in Kansas (Popenoe.)

Moneilema semipunctatum Le Conte.

On Opuntia in Kansas (Popenoe.)

Moneilema crassum Le Conte. Cotulla and Maverick counties, Tex., May (J. D. Mitchell); Encinal, El Paso, and Sabinal, Tex., April to September (F. C. Pratt).

Larvæ in roots; adults feed on joints.

Moneilema spoliatum Horn. Encinal, Tex., May (D. Griffiths).

Larvæ in roots; adults feed on joints.

Moneilema lævithorax White. Mex.

* *Moneilema gigas* Le Conte.

Moneilema armatum Le Conte.

Moneilema sp. Falfurrias, Tex., April (J. D. Mitchell).

Cœnopœus palmeri Le Conte. Bred from stems of *Opuntia bernardina*, Southern California.

Disonycha varicornis Horn. Devils River, Tex., May (E. A. Schwarz and F. C. Pratt); San Antonio and Austin, Tex., April, August, and June (F. C. Pratt). Confined to *Opuntia leptocaulis* and similar species.

Gerstæckeria hubbardi Le Conte. Breeds in the joints of *Opuntia vulgaris* following injury by *Melitara* sp.; taken at Crescent City and Lake Worth, Fla., and Selma, Ala. (H. G. Hubbard and E. A. Schwarz).

Gerstæckeria bifasciata Gerstaecker. Reared November 1, 1910, by F. L. Lewton from *Echinocactus setispinus* collected in June at San Antonio, Tex.

Gerstæckeria nobilis Le Conte. Breeds in the margins of the joints of *Opuntia engelmanni* and causes great masses of black excrement and gum to form on the outside of the joint. It has been taken at Dallas, Tex. (J. Boll); San Antonio, Tex., November (H. Soltau); San Diego, Tex., April, May, September (E. A. Schwarz); Beeville, Tex., April, eating fruit of Opuntia (C. L. Marlatt); Cotulla, Tex., April (F. C. Pratt); Live Oak County, Tex., June (J. D. Mitchell); Floresville, Tex., October (F. C. Pratt); Corpus Christi, Tex., May (A. C. Morgan), March (W. E. Hinds); Hondo, Tex., April (J. D. Mitchell); College Station, Tex., March (W. D. Pierce); Encinal, Tex., April (J. D. Mitchell); Victoria, Tex., April (J. D. Mitchell).

Gerstæckeria porosa Le Conte. Denver, Colorado Springs, Colo. (Wickham and Soltau); Sedalia, Colo. (H. Soltau); Albuquerque, N. Mex. (H. Soltau); Mesilla Park, N. Mex. (C. N. Ainslie); Kansas (Snow); Fort Grant, Ariz. (H. G. Hubbard and E. A. Schwarz); San Diego, Tex. (H. G. Hubbard and E. A. Schwarz); Floresville, Tex. (F. C. Pratt); Live Oak County, Tex. (J. D. Mitchell); D'Hanis, Tex. (J. D. Mitchell); Hondo, Tex. (F. C. Pratt).

The species breeds in flat cells in the discs of the joints of Opuntia.

Gerstæckeria basalis Le Conte. Denver, Colo. (H. Soltau); Greeley and Canon City, Colo. (H. Soltau); Sioux County, Nebr. (R. H. Wolcott).

Gerstæckeria clathrata Le Conte. San Diego, Tex., April and May, Laredo, Tex. May (H. G. Hubbard and E. A. Schwarz); Hidalgo, Tex. (G. Beyer); Uvalde, Tex., June (H. F. Wickham); Brownsville, Tex., June (C. H. T. Townsend); Santa Rita Mountains, Ariz., May (H. G. Hubbard and E. A. Schwarz).

Breeds in *Opuntia leptocaulis.*

Gerstæckeria turbida Le Conte. Catalina Springs, Ariz., April (H. G. Hubbard and E. A. Schwarz); Tucson, Ariz., January (H. G. Hubbard and E. A. Schwarz); Fort Grant, Ariz., July (H. G. Hubbard and E. A. Schwarz).

Gerstæckeria opuntiæ Pierce. Encinal, Tex., April (J. D. Mitchell).

Gerstæckeria cactophaga Pierce. Port Isabel, Tex., May (H. S. Barber); Brownsville, Tex. (C. H. T. Townsend).

Onychobaris mystica Casey. Southern Texas, Arizona, and New Mexico, on *Opuntia leptocaulis* (E. A. Schwarz); Tucson, Ariz., in *O. fulgida.*

**Cactophagus spinolæ* Gyllenhal (Syn.: *validus* Le Conte). (See Champion, Biol. Centr.-Amer.) California, Arizona, Mexico, many localities. Larva and pupa figured by Dugès (La Naturaleza, vol. 5, 121).

According to Dugès breeds in "*Cactus opuntia.*"

Cactophagus striatoforatus Gyllenhal. Attacks Cereus in Costa Rica and Colombia. (See Champion, Biol. Centr.-Amer., Coleoptera, vol. 4, 7, p. 84.

* *Cactopinus hubbardi* Schwarz. Forms mines in Cereus.

LEPIDOPTERA.

Apantesis arge Drury.

Feeding on cactus. (See Forbes, 23d Rept. Ins. Ill., p. 777, 1905.)

Chorizagrotis soror Smith. San Antonio, Tex., February (D. Griffiths).

Larvæ had formed canals through underground portions of plants. A serious enemy of young plantings. According to Dr. Dyar, it is probably a general feeder and not confined to cactus.

Mimorista flavidissimalis Grote. Widespread in Texas, south of San Antonio and west of Victoria. Brownsville, Victoria, and Beeville (J. D. Mitchell), San Antonio and Sabinal (F. C. Pratt); May to September. A very destructive insect, attacking joints of Opuntia.

Cornifrons elautalis Grote. Hondo, Tex. (J. D. Mitchell); Tucson, Ariz. Destructive to fruit.

Dicymolomia opuntialis Dyar. San Diego and Riverside, Cal., May (D. Griffiths). Apparently forms mines in joints, but doubtfully included in this list. See following species.

Dicymolomia julianalis Walker. Brownsville and Kerrville, Tex., June. Apparently forms mines in joints, but it is very doubtful whether it should be considered a cactus insect. Gahan (Proc. Ent. Soc. Wash., vol. 11, p. 66) records it as a predator on the eggs of *Thyridopteryx ephemeræformis* Haworth.

Ozamia lucidalis Walker. Victoria, San Antonio, and Hondo, Tex., May (J. D. Mitchell). Infesting fruit.

Melitara junctolineella Hulst. Kerrville, Tex. (H. Lacy); Corpus Christi, Victoria, Beeville, Hondo, Laredo, Tex. (J. D. Mitchell); El Paso, Kerrville, San Antonio, Tex. (F. C. Pratt). This and the other species of the genus live within the joints of Opuntia, causing large swellings. The two different kinds of cocoons seem to indicate that there are two species present in the cactus area. The range of the two forms corroborates this supposition. There are certain differences between the specimens, but they are not sufficient to separate the series into two forms.

Melitara prodenialis Walker. Florida (H. G. Hubbard); New Jersey (J. B. Smith); Biloxi, Miss., September (W. W. Tracy).

Melitara dentata Grote. Trinidad, Colo. (D. Griffiths).

**Melitara fernaldialis* Hulst. Santa Fe and Albuquerque, N. Mex., and Tucson, Ariz. (F. C. Pratt), on Opuntia; Tucson, Ariz. (H. G. Hubbard), on *Cereus giganteus*.

Platynota rostrana Walker. Brownsville, Tex., May (J. D. Mitchell).

Reared from Opuntia fruit. Reared in Florida by Dyar from Rivinia, Randia, and Gnaphalium.

Dyotopasta yumaella Kearfott. Brownsville, Tex. (J. D. Mitchell) and Arizona.

Breeds in fruit of Opuntia.

Marmara opuntiella Busck. At the following localities in Texas: Corpus Christi, Brownsville (J. D. Mitchell), San Antonio, Kerrville (F. C. Pratt), Marble Falls, New Braunfels (D. Griffiths). Mines beneath epidermis of joints.

HYMENOPTERA.

Polistes rubiginosus Lepeletier. Corpus Christi, Tex., August (J. D. Mitchell). This and the following species feed as adults on cracked fruit and sometimes on sound fruit of Opuntia.

* *Polistes flavus* Cresson. Arizona (H. G. Hubbard).

Polistes texanus Cresson. Alice, Brownsville, Corpus Christi, Tex., October (J. D. Mitchell); San Antonio, Tex. (F. C. Pratt).

DIPTERA.

Cecidomyia opuntiæ Felt. Reared in New York from joints of a European Opuntia (*O. banburjana*) and also from a West Indian species.

Asphondylia opuntiæ Felt. Los Angeles, Cal., April (D. Griffiths); Ash Fork, Ariz., May (D. Griffiths); Organ Mountains, N. Mex., January (D. Griffiths); Sinton, Victoria, Kennedy, Corpus Christi, Brownsville, Hondo, Cotulla, and Hallettsville, Tex. (J. D. Mitchell); Beeville, Tex., March (F. C. Pratt); San Luis Potosi, Mex. (D. Griffiths).

Breeds in fruit of Opuntia.

Asphondylia betheli Cockerell. Colorado.

In fruit of Opuntia.

Asphondylia arizonensis Felt. Arizona.

Reared from "enlargement of prickly pear."

PARASITES OR ENEMIES OF THE INJURIOUS SPECIES.

HEMIPTERA.

* *Sinea raptoria* Stål. Tucson, Ariz.

* *Diplodus luridus* Stål. Tucson, Ariz.

COLEOPTERA.

Exochomus latiusculus Casey. Corpus Christi, Seguin, San Antonio, Tex., March, October (F. C. Pratt); Cotulla and Beeville, Tex., April (J. D. Mitchell).

Exochomus marginipennis Le Conte. Corpus Christi, Hondo, Tex. (J. D. Mitchell); Seguin, Tex., October (F. C. Pratt).

Hippodamia convergens Guérin. Los Angeles, Cal., June (F. C. Pratt).

Feeds on aphides on Opuntia.

Cycloneda munda Say. Hondo, Tex., April (J. D. Mitchell).

Chilocorus cacti Linnaeus. Durango, Mex., November (F. C. Bishopp).

Hyperaspis trifurcata Schæffer. Hebbronville, Falfurrias, Floresville, Corpus Christi, Victoria, San Diego, Tex., May to August (J. D. Mitchell); Seguin, Alice, San Antonio, Kerrville, Tex. (F. C. Pratt); Durango, Mex. (F. C. Bishopp).

Hyperaspis cruenta Le Conte. Mesilla Park, N. Mex., June (D. Griffiths); Brewster County, Tex. (R. A. Cushman); El Paso, Tex., August (F. C. Pratt).

Scymnus loewii Mulsant. Brownsville, Tex., March (F. C. Pratt); Aguascalientes, Mex., December (F. C. Bishopp).

Scymnus hornii Gorham. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). The nine preceding species (except *Hippodamia convergens*) are enemies of *Dactylopius confusus.*

Bothrideres cactophagi Schwarz. Enemy of *Cactophagus validus.*

Trichodes bibaltcatus Le Conte. Cotulla, Tex., May (J. D. Mitchell); Dallas, Tex., May (F. C. Pratt).

Feeds upon Melitara and other insects.

Hydnocera pubescens Le Conte. Victoria, Tex., May (R. A. Cushman).

Feeds upon various cactus species.

LEPIDOPTERA.

Lætilia coccidivora Comstock. Cotulla, Tex., October.

Enemy of *Dactylopius confusus.*

Zophodia dilatifasciella Ragonot. San Antonio, Tex., June (D. Griffiths); Brown and Young Counties, Tex. (J. D. Mitchell).

Feeding on *Dactylopius confusus.*

Saluria ardiferella Hulst. Mesilla Park, N. Mex., June.

Feeds upon *Dactylopius confusus.*

HYMENOPTERA.

Mesostenus thoracicus Cresson. Corpus Christi, Tex., March (F. C. Pratt).

Probable parasite of *Melitara* spp.

Eiphosoma texana Cresson.

Parasite of *Mimorista flavidissimalis* Grote.

Eurytoma sp. D'Hanis, Tex., May (J. D. Mitchell).

Chelonus laticinctus Cresson. Trinidad, Colo., August.

Parasite of *Melitara dentata* Grote.

Apanteles (*Pseudapanteles*) sp. Corpus Christi, Tex., April (W. D. Pierce). At *Opuntia lindheimeri.*

Possible parasite of Melitara.

Apanteles sp. Victoria, Tex., September (J. D. Mitchell).

Possible parasite of Melitara.

DIPTERA.

Phorocera comstocki Williston. Victoria, Tex., October (J. D. Mitchell); San Antonio, Cotulla, Corpus Christi, Tex., October (F. C. Pratt).

Parasite of Melitara.

Drosophila punctulata Loew. San Antonio, Tex., April, May (D. Griffiths); Victoria, Tex., April, December (J. D. Mitchell); Brownsville, Tex., March (F. C. Pratt).

Feeds upon *Dactylopius confusus.*

Drosophila ampelophila Loew. Berkeley, Cal., June (D. Griffiths).
Feeds upon *Dactylopius confusus*.

Leucopis bella Loew. San Antonio, Tex., May (D. Griffiths); San Diego and San Bernardino, Cal.
Enemy of *Dactylopius confusus*.

Leucopis bellula Williston. Texas, New Mexico, and Mexico.
Enemy of *Dactylopius confusus*.

SCAVENGERS.

COLEOPTERA.

**Megasternum cerei* Schwarz.
**Dactylosternum cacti* Le Conte.
**Pelosoma capillosum* Le Conte.
**Eumicrus lucanus* Horn.
**Tyrus elongatus* Brendel.
**Melba puncticollis* Le Conte.
**Falagria* sp.
**Homalota* sp.
Aleochara sp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
Mascochara valida Le Conte. Reared by Coquillett from puparium of *Copestylum marginatum* Say in *Opuntia engelmanni* at Los Angeles, Cal.
**Mascochara semivelutina* Solsky.
**Mascochara spacella* Sharp.
**Mascochara puberula* Casey.
Mascochara sp. Arizona, June (F. C. Pratt).
**Apheloglossa rufipennis* Casey.
*Aleocharine, genus unknown.
**Oligota* sp.
**Xanthopygus cacti* Horn.
Belonuchus ephippiatus Say.
Belonuchus xanthomelas Solsky. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). Victoria and Hondo, Tex., December (J. D. Mitchell).
**Xantholinus dimidiatus* Le Conte.
**Lithocharis tabacina* Casey.
Tachinoderus grandis Sharp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Erchomus punctipennis* Le Conte.
**Erchomus convexus* Erichson. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Physetoporus grossulus* Le Conte.
Leptochirus edax Sharp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Omalium cacti* Schwarz.
**Trichopteryx* sp.
**Ephistemus cactophilus* Schwarz.
Attagenus piceus Olivier. D'Hanis and Encinal, Tex., May (J. D. Mitchell).
**Attagenus hornii* Jayne.
Carcinops sp. Aguascalientes, Mex., December (F. C. Bishopp).
Hololepta cacti Le Conte. San Antonio, Sabinal, and Hondo, Tex., May (F. C. Pratt); Victoria, Cotulla, Corpus Christi, Laredo, Tex. (J. D. Mitchell).

**Hololepta vicina* Le Conte.

Hololepta yucateca Marseul. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). According to Mr. E. A. Schwarz this species follows the attack of other species in Cereus and is of some importance in this connection.

Hololepta strigicolle Marseul. Mexico (Dugès).

**Paromalus opuntiæ* Le Conte.

**Paromalus consors* Le Conte.

**Paromalus gilensis* Le Conte.

Paromalus sp. Aguascalientes, Mex.

Saprinus pennsylvanicus Paykull. Cotulla, Tex., May (F. C. Pratt).

Terapus mniszechi Marseul (E. Dugès), Mexico. Although recorded by Dugès as a cactus insect Mr. Schwarz considers it strictly myrmecophilous.

**Acritus arizonæ* Horn.

Camptodes cacti Dugès.

This is a manuscript name. The species may be *C. heterocheilus* Sharp. Mexico.

**Holoparamecus pacificus* Le Conte.

**Alindria teres* Melsheimer.

Smicrips hypocoproides Reitter. Corpus Christi, Tex., March (W. D. Pierce).

Hyporhagus opuntiæ Horn. On Opuntia in Arizona (E. A. Schwarz and F. C. Bishopp).

Hyporhagus texanus Linell. San Diego, Tex., in decaying *Opuntia engelmanni* (E. A. Schwarz); Encinal and Hondo, Tex. (J. D. Mitchell).

Brachytarsus sp. Brownsville, Tex., March (C. R. Jones and F. C. Pratt).

DIPTERA.

**Ceratopogon* sp. Tucson, Ariz.

**Scatopse* sp. Tucson, Ariz.

Hermetia chrysopila Loew. San Antonio, Dallas, Encinal, Tex. (J. D. Mitchell and F. C. Pratt); Los Angeles, Cal., September (F. C. Pratt).

Hermetia hunteri Coquillett. Hondo, Encinal, Cotulla, Tex., May to October (F. C. Pratt and J. D. Mitchell).

Cyphomyia schaefferi Coquillett. Dallas, Tex., June.

Microdon globosus Fabricius. Dallas, Tex., May (C. R. Jones).

Nausigaster unimaculata Townsend. Cotulla, San Antonio, Tex., April (F. C. Pratt); Victoria, Tex. (J. D. Mitchell).

Reared from Opuntia.

Volucella pusilla Macquart. Various Texas localities: Victoria and Tivoli (J. D. Mitchell); Dallas, Corpus Christi, Cotulla, Beeville, San Antonio (F. C. Pratt).

Volucella fasciata Macquart. New Braunfels, Denton, Dallas, Tex., May (F. C. Pratt); Victoria, Tex., May (J. D. Mitchell); New Jersey (J. B. Smith).

**Volucella avida* Osten Sacken. Tucson, Ariz., December. In *Opuntia fulgida* and *Cereus giganteus.* (See Psyche, May, 1899.) Cotulla and San Antonio, Tex. (J. D. Mitchell); Encinal, Tex., April to June (F. C. Pratt).

Volucella esuriens Fabricius. At Texas localities below: Cotulla, Kerrville, Hebbronville, San Diego (F. C. Pratt); Live Oak County, San Antonio, Alice, Corpus Christi (J. D. Mitchell), March to May.

Copestylum marginatum Say. San Antonio, Falfurrias, Mathis, Live Oak County, Kerrville, Encinal, Cotulla, Hondo, Dallas, Tex. (various localities by J. D. Mitchell and F. C. Pratt); Los Angeles and Riverside, Cal. (F. C. Pratt).

Hilarella decens Townsend. Albuquerque, N. Mex., June (F. C. Pratt).
Helicobia quadrisetosa Coquillett. Corpus Christi, Tex., March (F. C. Pratt).
Musca domestica Linnaeus. San Luis Potosi, Mex., June (Rose).
In decaying fruit.
Phorbia fusciceps Zetterstedt. Riverside, Cal., May (D. Griffiths).
Sapromyza vulgaris Fitch. Riverside, Cal., May (D. Griffiths).
Rivellia sp. (?) Corpus Christi and San Antonio, Tex. (F. C. Pratt), March to June.
**Limosina* sp. Tucson, Ariz.
Stictomyia longicornis Bigot. Generally distributed in Texas and Mexico. Taken at the following localities in Texas: Victoria, Encinal, Hondo, D'Hanis, Tivoli, San Diego, Kingsville, Corpus Christi (J. D. Mitchell); Sabinal, Kerrville, San Antonio (F. C. Pratt); Brownsville (D. Griffiths), March to November. In Mexico at Durango, December (F. C. Bishopp and E. A. Schwarz).
**Xerius flavifrons* Bigot. Tucson, Ariz.

SPECIES WHICH MERELY FREQUENT THE FLOWERS.

COLEOPTERA.

Carpophilus pallipennis Say. San Antonio, Encinal, Hondo, D'Hanis, Corpus Christi, Tex., May (J. D. Mitchell); Dallas, Tex. (F. C. Pratt); Los Angeles, Cal. (F. C. Pratt), June; San Pedro and Riverside, Cal., May (D. Griffiths).
Acmæodera tubulus Fabricius. D'Hanis, Tex., May (J. D. Mitchell); Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt).
Acmæodera quadrivittata Horn. El Paso, Tex., August (F. C. Pratt).
Acmæodera pulchella Herbst. Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt).
**Lycaina discoidalis* Horn. Arizona.
Chauliognathus scutellaris Le Conte. D'Hanis, Tex., April (J. D. Mitchell).
Listrus sp. Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt); Brownsville, Tex., April (C. R. Jones and F. C. Pratt).
Euphoria kernii Haldeman. Encinal, San Antonio, and Zavalla County, Tex., May (F. C. Pratt and D. Griffiths); Hondo, D'Hanis, and Brownsville, Tex. (J. D. Mitchell).
Colaspoides macrocephalus Schaeffer. D'Hanis, Tex., May (J. D. Mitchell).
Nodonota tristis Olivier. D'Hanis, Tex., May (J. D. Mitchell).
Leptinotarsa haldemani Rogers. Victoria, Tex., May (J. D. Mitchell).
Under Opuntia.
Chrysomela auripennis Say. Victoria, Tex., May (J. D. Mitchell).
Luperodes brunneus Crotch. Victoria, Tex., April (J. D. Mitchell).
Eupogonius vestitus Say (?). Victoria, Tex., May (J. D. Mitchell).
Diabrotica 12-punctata Olivier. Los Angeles, Cal., June (F. C. Pratt).
Phyllotreta pusilla Horn. D'Hanis, Tex., April (J. D. Mitchell).
Bruchus sp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp); Tucson, Ariz., May (F. C. Pratt).
Epicauta trichrus Pallas. Hondo and D'Hanis, Tex., May (J. D. Mitchell).

HYMENOPTERA.

Chrysis sp. Victoria, Tex., April (R. A. Cushman).
Halictus sp. Los Angeles, Cal., June (F. C. Pratt).

Dialictus occidentalis Crawford. Flagstaff, Ariz., June (F. C. Pratt). At Echinocereus.

Augochlora neglectula Cockerell. New Mexico. At *Echinocactus wislizeni* (T. D. A. Cockerell).

Agapostemon texanus Cresson. New Mexico. At *Cereus polyacanthus* and *C. pendleri?* (T. D. A. Cockerell); Flagstaff, Ariz., June (F. C. Pratt).

Perdita megacephala Cresson. Hondo, Tex., April (J. D. Mitchell).

Ashmeadiella cactorum Cockerell. Santa Fe, N. Mex., on *Cactus radiosus neomexicanus* (Eng.) (T. D. A. Cockerell).

Ashmeadiella opuntiæ Cockerell. New Mexico, on Opuntia (T. D. A. Cockerell).

Ashmeadiella echinocerei Cockerell. Flagstaff, Ariz., at *Echinocereus* sp (F. C. Pratt).

Heriades gracilior Cockerell. New Mexico, on Opuntia (T. D. A. Cockerell).

Lithurgus echinocacti Cockerell. New Mexico, on *Echinocactus wislizeni* (T. D. A. Cockerell).

Lithurgus apicalis opuntiæ Cockerell. New Mexico. At *Opuntia arborescens* (T. D. A. Cockerell); Zavalla County and Sabinal, Tex., and Tucson, Ariz. (F. C. Pratt).

Megachile populi Cockerell (Syn.: *M. opuntiarum* Cockerell, *fide* Cockerell). Colorado (T. D. A. Cockerell).

Megachile sidalceæ Cockerell. New Mexico. On *Opuntia engelmanni* (T. D. A. Cockerell).

Melissodes pallidicincta Cockerell. Colorado (T. D. A. Cockerell).

Melissodes opuntiella Cockerell. Brownsville, Tex. (F. C. Pratt); Hondo, Tex. (J. D. Mitchell).

Diadasia australis Cresson. New Mexico and Colorado, on *Opuntia arborescens* (T. D. A. Cockerell); Cotulla, Hondo, D'Hanis, and Zavalla County, Tex., April (F. C. Pratt).

D. australis opuntiæ Cockerell. Southern California, on *Opuntia littoralis* (Eng.) (T. D. A. Cockerell); Los Angeles, Cal., June (F. C. Pratt).

Diadasia australis rinconis (Cockerell). New Mexico. *Opuntia engelmanni* and *O. arborescens* (T. D. A. Cockerell); Runge, Zavalla County, and Brownsville, Tex., March (F. C. Pratt); Cotulla, Tex., April (J. D. Mitchell), on *O. leptocaulis* and *O. lindheimeri;* Los Angeles, Cal. (F. C. Pratt).

Diadasia piercei Cockerell. Beeville, Tex. (C. L. Marlatt).

Diadasia bituberculata Cresson. Los Angeles, Cal.

DIPTERA.

Mesogramma marginata Say. Hondo, Tex., April (J. D. Mitchell).

SPECIES INCIDENTALLY ASSOCIATED WITH THE PLANT.

ORTHOPTERA.

Spongophora apicidentata Caudell. Aguascalientes, Mexico, December (F. C. Bishopp).

* *Spongophora brunneipennis* Serville. Tucson, Ariz.

Dichromorpha viridis Scudder. Laredo, Tex., May (J. D. Mitchell).

Dichopetala brevihastata Scudder. Alice, Corpus Christi, and Maverick County, Tex., May (J. D. Mitchell and F. C. Pratt).

Dichopetala emarginata Brunner. Hebbronville, Tex., May (J. D. Mitchell).

Dichopetala sp. Encinal, Tex., April.

Stipator nigromarginata Caudell. Corpus Christi, Tex. (J. D. Mitchell); Alice, Encinal, and Maverick County, Tex. (J. D. Mitchell).

Stipator haldemanni Girard. San Antonio, Tex., April (W. D. Hunter and F. C. Pratt).

Stipator mitchelli Caudell. Alice and Hondo, Tex., April (J. D. Mitchell).

Stipator pratti Caudell. Alice, Tex., August (J. D. Mitchell).

Stipator grandis Rehn. Corpus Christi, Tex., August (J. D. Mitchell).

Rehnia spinosa Caudell. Cotulla, Encinal, and Hondo, Tex., May (F. C. Pratt); Maverick County and Hebbronville, Tex. (J. D. Mitchell).
Feeding on petal of Opuntia.

HEMIPTERA.

**Brochymena obscura* Herrich-Schaeffer. San Antonio, Tex., November (J. D. Mitchell); Tucson, Ariz. (H. G. Hubbard).

Anasa tristis Say. Sabinal, Tex., December (F. C. Pratt).
Under Opuntia.

Nysius ericæ Schilling (Syn.: *angustatus* Uhler). San Antonio, Tex., June (E. S. Tucker).

Ligyrocoris pseudoheræus Barber. San Antonio, Tex., November (J. D. Mitchell).
Under Opuntia.

Tempyra biguttula Stål. D'Hanis, Tex., April (J. D. Mitchell).

Cnemodus mavortius Say. Sabinal, Tex., December (F. C. Pratt).
Under Opuntia.

Lygæus abulus Distant. San Antonio, Tex., September (J. D. Mitchell).
Under Opuntia.

COLEOPTERA.

Pasimachus californicus Chaudoir. Encinal, Tex., April (J. D. Mitchell).

Pasimachus depressus Fabricius. San Antonio and Cotulla, Tex. (F. C. Pratt).

Dicælus costatus Lec. Encinal, Tex., April (J. D. Mitchell).

Discoderus impotens Le Conte. Hondo, Tex., June (J. D. Mitchell).

Cercyon sp. Aguascalientes, Mexico, December (F. C. Bishopp).

Rhagodera sp. Encinal, Tex., April (J. D. Mitchell).

**Ditoma gracilis* Sharp.

**Ditoma sulcata* Le Conte.

**Bothrideres denticollis* Dugès, MS. Mexico.

Agrypnus sallei Le Conte. Cotulla, Tex., May (J. D. Mitchell).

Chalcolepidius viridipilis Say. D'Hanis, Tex., May (J. D. Mitchell).

Diplotaxis truncatula Le Conte. Encinal, Tex., May (J. D. Mitchell).

Phileurus cribrosus Le Conte. Encinal and Hondo, Tex., April (J. D. Mitchell).

Ataxia crypta Say. Hondo, Tex., March (J. D. Mitchell).

Triorophus nodiceps Le Conte. Encinal and Cotulla, Tex., May (J. D. Mitchell).

Eurymetopon muricatulum Casey. Tucson, Ariz., May (F. C. Pratt).

Emmenastus texanus Le Conte. Encinal and Cotulla, Tex., May (J. D. Mitchell).

Noserus emarginatus Horn. Hondo, Tex., May (J. D. Mitchell).

Centrioptera variolosa Horn. Tucson, Ariz., May (F. C. Pratt).

Centrioptera infausta Le Conte. Cotulla, Tex. (J. D. Mitchell). Under fallen Opuntia leaves. Encinal, Tex., May.

Eleodes tricostata Say. Encinal, Tex., May (J. D. Mitchell).

Eleodes texana Le Conte. Oakville, Tex., December (J. D. Mitchell).

Eleodes ventricosa Le Conte. Hondo, Tex., November (F. C. Pratt).
Eleodes armata Le Conte. Tucson, Ariz., May (F. C. Pratt).
Eleodes carbonaria Say. Tucson, Ariz., May (F. C. Pratt); Cotulla, Tex. (J. D. Mitchell).
Eleodes carbonaria var. *soror* Le Conte. Cotulla, Tex. (J. D. Mitchell).
Anthicus infernus La Ferté-Sénectère. Mexico.
Blapstinus pratensis Le Conte. Hondo, Corpus Christi, Encinal, Cotulla, Tex., March to November (J. D. Mitchell); Hondo, Tex., November (F. C. Pratt).
**Ulosonia marginata* Le Conte.
**Cynæus angustus* Le Conte.
Helops farctus Le Conte. Hondo, Tex., May (J. D. Mitchell).
Othnius seneciónis Champion. Durango, Mexico, November (F. C. Bishopp); Aguascalientes, Mex., December (F. C. Bishopp); Texas (E. A. Schwarz).
Compsus auricephalus Say. Hondo, Tex., April (J. D. Mitchell).
Colecoerus marmoratus Say. D'Hanis, Tex., May (J. D. Mitchell).
Smicronyx spretus Dietz. San Antonio, Tex., June (J. C. Crawford).
On Opuntia.
Calandra remota Sharp. "Occurs commonly in the stems of banana and prickly pear near Honolulu." (Mem. Coleoptera Hawaiian Islands, p. 183.)
**Apotrepus densicollis* Casey.
**Cossonus hubbardi* Schwarz.

LEPIDOPTERA.

Kricogonia lyside Godart. Encinal, Tex., May (J. D. Mitchell).
Pontia protodice Boisduval. Encinal, Tex., April (J. D. Mitchell).
Campometra impartialis Harvey. Cotulla, Tex., April (J. D. Mitchell). Pupa found under dead Opuntia joints.
Lineodes integra Zeller. San Antonio, Tex., September.
On Opuntia.
"I bred this on Solanaceæ."—H. G. Dyar.

HYMENOPTERA.

Stomatocera rubra Ashmead. Corpus Christi, Tex., April (F. C. Pratt).
**Pachycondyla harpax* F. Smith. Hondo, Tex., May (J. D. Mitchell).
Under dead Opuntia leaves.
Neoponera villosa F. Smith. Falfurrias, Tex., April (J. D. Mitchell).
Nesting in leaves of dead cacti.
Odontomachus clarus Roger (?). Hondo, Tex., June (J. D. Mitchell).
Crawling under dead Opuntia.
Pseudomyrma brunnea F. Smith. Aguascalientes, Mex., December (F. C. Bishopp); Corpus Christi, Tex. (F. C. Pratt).
Pheidole sp. Los Angeles, Cal., June (F. C. Pratt).
Under decaying Opuntia, carrying dipterous larvæ.
Cremastogaster lineolata Say. Hondo, Tex., May (J. D. Mitchell)
Under dead Opuntia leaves.
Cremastogaster sp. Tucson, Ariz., May (F. C. Pratt).
Attending aphis on *Opuntia versicolor* and *O. fulgida.*
Leptothorax sp. Victoria, Tex., April (J. D. Mitchell).
Nesting in green fruit of Opuntia.
Dorymyrmex pyramicus Roger var. *flavus* McCook. Los Angeles, Cal., June (F. C. Pratt).
On Opuntia fruit.

Iridomyrmex analis Ernest André. El Paso, Tex., May (F. C. Pratt), in Opuntia bloom; Tucson, Ariz., May (F. C. Pratt), attending aphis on *Opuntia versicolor, O. engelmanni,* and *O. fulgida.*

Forelius maccooki Forel. Laredo, Tex., August (J. D. Mitchell).
Eating Opuntia fruit opened by some other insect.

Prenolepis viridula Nylander, subsp. *melanderi* Wheeler. Victoria, Tex., March (J. D. Mitchell).
In green Opuntia fruit.

Formica subpolita Mayr, var. Flagstaff, Ariz., June (F. C. Pratt).
Attending aphis on Echinocereus.

Myrmecocystus melliger Forel, var. Brownsville, Tex., April (R. A. Cushman), on Opuntia; Hondo, Tex., May (J. D. Mitchell), under dead leaves of Opuntia; Albuquerque, N. Mex., June (F. C. Pratt), on *Opuntia arborescens.*

Camponotus maculatus vicinus Mayr, var. *nitidiventris* Emery. Albuquerque, N. Mex., May (F. C. Pratt).
On *Opuntia arborescens.*

Camponotus sp. Bee County, Tex., May (J. D. Mitchell).
Nest in root hole of dead Opuntia.

Pycnomutilla texana Blake. Hondo, Tex., April (J. D. Mitchell).

Dasymutilla orcus Cresson. Corpus Christi, Tex., August (J. D. Mitchell).

Paratiphia sp. Tucson, Ariz., May.

Compsomeris 4-notata Fabricius. Victoria, Tex., April (H. P. Wood).

Odynerus clusinus Cresson. San Diego, Tex., April (F. C. Pratt).

Euglossa surinamensis Linnæus. Brownsville, Tex., March (F. C. Pratt).
On *O. lindheimeri.*

Eucœla sp.

DIPTERA.

Atomosia puella Wiedemann. D'Hanis, Tex., May (J. D. Mitchell).

Epicromyia floridensis Townsend. "Pratt-Cactus in winter."

Notogramma stigma Fabricius. San Antonio, Tex., June (F. C. Pratt).

Epiplatea scutellata Wiedemann. Corpus Christi, Tex., March (F. C. Pratt); San Antonio, Tex., March (F. C. Pratt).

Chlorops quinquepunctata Loew. Los Angeles, Cal., June (F. C. Pratt).

Oscinis coxendix Fitch. Reared at Washington, D. C., from material from unknown locality.

NOTE.—In Insect Life, vol. 3, p. 402, will be found a note on injury to *Mammillaria phellosperma* by undetermined sowbugs. Hubbard recorded two species of Gamasidæ and two of Pseudoscorpionidæ from the pulp of *Cereus giganteus.*

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62d Congress } SENATE { Document
2d Session } { No. 305

MEXICAN COTTON-BOLL WEEVIL

MESSAGE FROM THE
PRESIDENT OF THE UNITED STATES

TRANSMITTING

A COMMUNICATION FROM THE
SECRETARY OF AGRICULTURE
SUBMITTING A REPORT ON THE
MEXICAN COTTON-BOLL WEEVIL

WASHINGTON
1912

COTTON PLANT ATTACKED BY BOLL WEEVIL.

a, Hanging dry square infested by weevil larva; *b*, flared square, with weevil punctures; *c*, cotton boll, sectioned, showing attacking weevil and weevil larva in its cell. (Original.)

62d Congress, 2d Session | SENATE | Document No. 305

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UNITED STATES OF AMERICA
GOVERNMENT PRINTING OFFICE

LETTER OF TRANSMITTAL.

To the Senate and House of Representatives:

I transmit herewith for the information of the Congress a communication from the Secretary of Agriculture, accompanying the manuscript of a report on the Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911. (Bulletin No. 114, Bureau of Entomology.)

The report contains valuable information of great public interest to cotton planters of this country and those depending upon the cotton-plant industry, and I cordially indorse the recommendation of the Secretary that the report be printed for distribution by Congress as well as by the department.

WM. H. TAFT.

THE WHITE HOUSE, *February 12, 1912.*

LETTERS OF SUBMITTAL.

Department of Agriculture,
Office of the Secretary,
Washington, February 8, 1912.

To the President of the United States.

Mr. President: I have the honor to submit herewith, for your information and that of the Congress of the United States, a bulletin entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," by Messrs. W. D. Hunter and W. D. Pierce of this department. This is an elaboration of a bulletin published in 1905 and of which a special edition was ordered by Congress. Since that date the weevil has spread throughout the State of Louisiana and has entered the States of Arkansas, Mississippi, and Alabama, and threatens to spread throughout the entire cotton-growing area east of the arid regions. In the course of this eastward and northward spread, new conditions have been encountered; the habits and life history of the weevil have undergone some change, and it has met with new parasites and natural enemies. There is a great demand among the cotton planters of this country and among those dependent upon the cotton-planting industry for the information contained in this bulletin, and, in view of this fact, I respectfully recommend that this report be transmitted to Congress, together with the maps, illustrations and diagrams accompanying it, to be printed by order of Congress; and I further recommend that not less than 10,000 copies be printed for the use of this department, in addition to such number as Congress may order for the use of its Members.

I have the honor to remain, Mr. President,

Very respectfully,

James Wilson, *Secretary.*

Department of Agriculture.
Bureau of Entomology,
Washington, D. C., January, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication a manuscript entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," prepared by Messrs. W. D. Hunter and W. D. Pierce, of this bureau.

This manuscript contains in the briefest possible space an account of the exhaustive investigations of the Mexican cotton-boll weevil which have been conducted by this bureau for some years past. The last comprehensive bulletin on this subject was issued in 1905 and is now far out of date. There is urgent demand for information on this important pest, and this demand will undoubtedly continue as the insect invades new regions.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Early in 1905 the Bureau of Entomology published as Bulletin 51 an account of the information concerning the Mexican cotton-boll weevil which was available at that time. Since 1905 the work on the investigation of this important insect has been continued by the Bureau of Entomology and by various other agencies. As the result of this recent work certain features of the life history of the pest have received full treatment in publications of the bureau. This is the case with hibernation,[1] natural control,[2] parasites,[3] proliferation,[4] and repression.[5] Important contributions have been made by State agencies. The result has been that the original bulletin has been out of date for some time. On many topics the amount of information now available is more than double that at hand at the time the previous publication was issued. Moreover, it seems advisable that the history of the pest in the United States and an account of the losses occasioned by it should be brought up to date. For these reasons the present publication has been prepared to include all of the more important available information concerning the boll weevil. It is based upon Bulletin 51, from which many extracts have been used, and will supersede that publication.

In the nature of the case it is impossible to include all of the data which have been published with reference to certain phases of the life history of the boll weevil, such as hibernation and parasite control. In all such cases, however, the main essentials regarding these special topics have been incorporated. Persons who desire more detailed information may consult the various special publications, which are still available.

As might be supposed the accumulation of many additional data has necessarily changed some of the conclusions drawn in the earlier publication. It is to be noted, however, that these changes are generally of little consequence.

The investigation of the boll weevil was begun by the then Division of Entomology in 1895 and has been continued, more or less constantly, to the present date. The vast amount of information which has thus been accumulated is to be credited to a large number of entomologists, many of whom are now doing work in other fields, The earlier investigations of the weevil were conducted by Dr. L. O. Howard and Messrs. C. L. Marlatt, C. H. T. Townsend, E. A. Schwarz. and Frederick Mally. The State officers who have assisted materially in this work have been the entomologists of Texas, Messrs. E. D. Sanderson, A. F. Conradi, C. E. Sanborn, and Wilmon Newell; of Louisiana, Messrs. H. A. Morgan, Wilmon Newell, J. B. Garrett,

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[4] Bull. 59, Bur. Ent., U. S. Dept. Agr., 1906.
[5] Farmers' Bull. 344, U. S. Dept. Agr., 1909.

T. C. Barber, H. Dean, M. S. Dougherty, A. H. Rosenfeld, and G. A. Runner; of Oklahoma, Messrs. C. E. Sanborn and A. L. Lovett; of Arkansas, Dr. George F. Adams; of Mississippi, Messrs. Glenn W. Herrick, R. W. Harned, S. F. Blumenfeld, and R. N. Lobdell; and of Alabama, Dr. W. E. Hinds and Messrs. W. F. Turner and I. W. Carpenter. The work has been facilitated by the commissioners of agriculture of the various States, including Col. Charles Shuler, former commissioner of agriculture of Louisiana, Mr. H. E. Blakeslee, commissioner of agriculture of Mississippi, and Mr. F. W. Gist, former commissioner of agriculture of Oklahoma.

The agents of the Bureau of Entomology who have contributed to this bulletin are: Messrs. F. C. Bishopp, J. C. Crawford, R. A. Cushman, F. L. Elliott, A. F. Felt, C. W. Flynn, J. B. Garrett, W. H. Gilson, S. Goes, G. H. Harris, W. E. Hinds, W. H. Hoffman, T. E. Holloway, C. E. Hood, W. A. Hooker, R. C. Howell, C. R. Jones, B. T. Jordan, O. M. Lander, Thomas Lucas, E. A. McGregor, J. D. Mitchell, A. C. Morgan, A. W. Morrill, D. C. Parman, T. C. Paulsen, H. Pinkus, F. C. Pratt, V. I. Safro, E. A. Schwarz, J. S. Slack, G. D. Smith, H. S. Smith, C. S. Spooner, E. S. Tucker, G. N. Wolcott, and W. W. Yothers. Of these agents Dr. W. E. Hinds, who for several years was the principal assistant in the cotton boll weevil investigations of this bureau, was the most extensive contributor. To him we owe a large share of the accurate data on the life history and habits of the boll weevil. He also did a large amount of work in the preparation of Bulletin 51, upon which this publication is based. We have attempted throughout the bulletin to credit the various agents with the work for which they have been directly responsible, but in this place it must be stated that the results obtained are due to the faithful and efficient service of the whole corps of entomologists who have been associated with the writers. The work has also been greatly facilitated by the constant interest and encouragement of the chief of the bureau.

Special credit is due to Mr. E. S. Tucker for skillful preparation of the plates.

THE AUTHORS.

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THE MEXICAN COTTON-BOLL WEEVIL: A SUMMARY OF THE INVESTIGATION OF THIS INSECT UP TO DECEMBER 31, 1911.

ORIGIN AND HISTORY.

There is very little certainty regarding the history of the Mexican cotton-boll weevil before its presence in Texas came to the attention of the Division of Entomology in 1894. The species was described by Boheman in 1843 from specimens received from Vera Cruz, and was recorded by Suffrian in 1871 as occurring at Cardenas and San Cristobal, in Cuba. Written documents in the archives at Monclova, in the State of Coahuila, Mexico, indicate that the cultivation of cotton was practically abandoned in the vicinity of that town about the year 1848, or at least that some insect caused very great fears that it would be necessary to abandon the cultivation of cotton. A rather careful investigation of the records makes it by no means clear that the insect was the boll weevil, although there is a rather firmly embedded popular opinion in Mexico, as well as in the southern United States, that the damage must have been perpetrated by that species. So far as the accounts indicate, it might have been the bollworm (*Heliothis obsoleta* Fab.) or the cotton caterpillar (*Alabama argillacea* Hübn.).

From the time of the note by Suffrian regarding the occurrence of the weevil in Cuba in 1871, up to 1885, there has been found no published record concerning it. In 1885, however, Dr. C. V. Riley, then Entomologist of the Department of Agriculture, published in the report of the Commissioner of Agriculture a very brief note to the effect that *Anthonomus grandis* had been reared in the department from dwarfed cotton bolls sent by the late Dr. Edward Palmer from northern Mexico.[1] This is the first account in which the species is associated with damage to cotton. The material referred to was collected in the State of Coahuila, presumably not far from the town of Monclova.

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[1] The following is a copy of the original letter by Dr. Palmer:

EAGLE PASS, TEX., *Sept. 28, 1880.*

The COMMISSIONER OF AGRICULTURE.

SIR: Previous to leaving Monclova, Mexico, for this place I visited some fields planted with cotton. Seeing but few bolls of cotton, examination revealed the cause. An insect deposits its egg and the boll falls; thus some plants had only two or three, others five or six bolls, while underneath the leaves, in the shade thereof, were many that had fallen there in the moist shade to lay for the larva to hatch. Please find inclosed insects and many of the injured bolls, some newly punctured, others taken from under the plant.

Monclova, Mexico, and the surrounding country a few years ago was famous for its large supply of cotton; at this time none can be grown, owing to the destructive insect, samples of which are sent. The inhabitants would be glad to hear of a remedy, upon which matter in the future I will communicate with your department.

Your obedient servant, EDWARD PALMER.

The specimens were sent by Dr. L. O. Howard to Mr. Henry Ulke, who transmitted them to Dr. George Horn, of Philadelphia. In turn Dr. Horn forwarded the material to Dr. Sallé, in Paris, who made the determination.

After the American occupation of Cuba the boll weevil began to attract considerable attention in that island. In 1902 it was observed that the weevil was quite injurious to cotton at Cayamas, Cuba. This place was visited by Mr. E. A. Schwarz, of the Bureau of Entomology, in the spring of 1903. He found that the native food plants of the weevil in Cuba were the "wild" or "loose" cotton (*Gossypium brasiliense*) and the native "kidney" cotton—both tree cottons.

The spread of the boll weevil in Mexico appears to have begun prior to 1892. In that year it appeared at Sabinas, State of Coahuila, and about this time or earlier it appeared at San Juan Allende, Morelos, Zaragoza, and Matamoras, Mexico. It crossed the Rio Grande at Brownsville probably before 1892. At any rate, during that year it caused considerable loss at Brownsville. In 1894 it had spread to half a dozen counties in the Brownsville region, and during the last months of the year was brought to the attention of the Division of Entomology as an important enemy of cotton. Mr. C. H. T. Townsend was immediately sent to the territory affected. His report, published in March, 1895, dealt with the life history and habits of the insect, which were previously entirely unknown, the probable method of its importation, and the damage that might result from its work, and closed with recommendations for fighting it and preventing its further advance in the cotton-producing regions of Texas. It is much to be regretted that at that time the State of Texas did not adopt the suggestion made by the Bureau of Entomology that a belt be established along the Rio Grande in which the cultivation of cotton should be prohibited, and thus the advance of the insect be cut off.[1] The events of the last few years have verified the predictions of the Division of Entomology in view of the advance made and the damage caused by the insect.

In 1895 the insect was found by the entomologists of the Division of Entomology, who continued the investigation started the year before, as far north as San Antonio and as far east as Wharton. Such a serious advance toward the cotton-producing region of the State caused the Bureau of Entomology to continue its investigations during practically the whole season. The results of this work were incorporated in a circular by Dr. L. O. Howard, published early in 1896, in both Spanish and English editions.

An unusual drought in the summer of 1896 prevented the maturity of the fall broods of the weevil, and consequently there was no extension of the territory affected. During 1896 the investigations were continued, and the results published in another circular issued in February, 1897. This circular was published in Spanish and German as well as English editions, for the benefit of the very large foreign population in southern Texas.

The season of 1897 was in many respects almost as unfavorable as that of 1896, but the pest increased its range to the region about Yoakum and Gonzales. Although this extension was small, it was exceedingly important, because the richest cotton lands in the United States were beginning to be invaded. The problem had thus become so important that Mr. C. H. T. Townsend was stationed

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[1] This suggestion was brought to the attention of the General Assembly of Texas by the then Assistant Secretary of Agriculture, Dr. C. W. Dabney, who went to Austin for that purpose.

in Mexico, in a region supposed to be the original home of the insect, for several months to discover, if possible, any parasites or diseases that might be affecting it, with the object of introducing them to prey upon the pest in Texas. Unfortunately, nothing was found that gave any hope of material assistance in the warfare against the weevil.

The season of 1898 was very favorable for the insect. Investigations by the Bureau of Entomology were continued, and a summary of the work, dealing especially with experiments conducted by Mr. C. L. Marlatt in the spring of 1896, was published in still another circular. During this year the first of a long series of conventions to discuss the boll weevil was held. This meeting took place at Victoria, Tex., on October 12, and was attended by many planters, bankers, and merchants.

At this time the Legislature of the State of Texas made provision for the appointment of a State entomologist and provided a limited appropriation for an investigation of means of combating the boll weevil. In view of this fact the Bureau of Entomology discontinued temporarily the work that had been carried on through agents kept in the field almost constantly for four years, and all correspondence was referred to the State entomologist of Texas. Unfortunately, however, the insect continued to spread, and it soon became apparent that other States were threatened. This caused the work to be taken up anew by the Bureau of Entomology in 1901, in accordance with a special appropriation by Congress for an investigation independent of that which was being carried on by the State of Texas, and with special reference to the discovery, if possible, of means of preventing the insect from spreading into adjoining States.

In accordance with the provision mentioned the senior writer was sent to Texas in March, 1901, and remained in that State until December. He carried on cooperative work upon eight large plantations in the region infested by the weevil. The result of his observations was to suggest the advisability of a considerable enlargement of the scope of the work. It had been found that simple cooperative work with the planters was exceedingly unsatisfactory. The need of a means of testing the recommendations of the Bureau of Entomology upon a large scale, and thereby furnishing actual demonstrations to the planters, became apparent. Consequently, in 1902, at the suggestion of the Department of Agriculture, provision for the enlargement of the work was made by Congress. Agreements were made with two large planters in typical situations for testing the principal features of the cultural system of controlling the pest upon a large scale. At the same time the headquarters and laboratory of the special investigation were established at Victoria. The results of the field work for this year were published in the form of a Farmers' Bulletin. During this season cooperation was carried on with the Mexican commission charged with the investigation of the boll weevil in that country, which was arranged on the occasion of a personal visit of Dr. L. O. Howard to the City of Mexico in the fall of the preceding year. In November an enthusiastic convention of planters and merchants to discuss the problems was held at Dallas, Tex.

The favorable reception by the planters of Texas of the experimental field work conducted during 1902 and the increase in the

territory occupied by the pest brought about an enlarged appropriation for the work of 1903. It thus became possible to increase the number and size of the experimental fields as well as to devote more attention to the investigation of matters suggested by previous work in the laboratory. Seven experimental and demonstrational farms, aggregating 558 acres, were accordingly established in as many distinct cotton districts in Texas.

During 1903 the weevil was recorded from San Juan, Guatemala, by G. C. Champion. In this same year it was discovered that the weevils were being introduced in cottonseed into the "Laguna" district in the State of Coahuila, Mexico, but effective measures were taken by the Mexican authorities, and the infestation was suppressed. Since that time the weevil has never been recorded from this important cotton region. The year 1903 is also important as being that in which the weevil first crossed the Sabine River into Sabine and Calcasieu Parishes in Louisiana. Another feature of the year was a large boll-weevil convention held at Dallas, Tex., which established a permanent organization and issued a number of valuable circulars relating to the problem. A similar meeting was held in New Orleans on November 30, at which the governor of the State presided.

In 1904 a general realization of the great damage done by the boll weevil led to the appropriation by Congress of $250,000 for use in enabling the Secretary of Agriculture to meet the emergency caused by the ravages of the insect. It thus became possible again to increase the number of experimental farms and to pay especial attention to a number of important matters that could not be investigated previously. The large appropriation was used in part to establish the demonstration work of the department. The object of this work was to demonstrate the methods of control perfected and demonstrated previously by the Bureau of Entomology. It has gradually developed into the well-known Farmers' Cooperative Demonstration Work of the Bureau of Plant Industry.

With the advent of the weevil into Louisiana that State began energetic work against the pest. Largely through the efforts of Prof. W. C. Stubbs an extraordinary session of the legislature was convened early in 1904. The action decided upon was the establishment of the Crop Pest Commission of Louisiana, with full authority to take such a course as might be found advisable. Prof. H. A. Morgan became secretary and entomologist of the commission. In 1905 Prof. Morgan was succeeded by Mr. Wilmon Newell, who continued the cooperative investigations with the Bureau of Entomology throughout the period of his services in Louisiana, which extended to January 31, 1910.

During 1904 two conventions were held at Shreveport, La. The first discussed especially the local features of the problem, while the second, which was held in November, was national in its scope. It was attended by delegates from most of the Southern States.

The year 1904 witnessed an extensive dispersion of the weevil into new regions in Texas and Louisiana. During this year, Dr. O. F. Cook, of the Bureau of Plant Industry, found the weevil thoroughly established in Alta Vera Paz, Guatemala.

At the beginning of 1905 the laboratory of the bureau was moved from Victoria to Dallas, Tex., where it has since remained. The

observations on the activities of the boll weevil in this year were considerably limited, owing to restrictions on travel imposed by the yellow-fever quarantine. The insect was found, however, at Mazatlan, State of Sinaloa, on the Pacific coast of Mexico, on March 20, 1905.

In 1906 the weevil spread extensively to the west in Texas, a considerable distance northward into Oklahoma, into Arkansas, and almost to the Mississippi River in Louisiana. During this season Mr. M. T. Cook recorded the weevil from Santiago de las Vegas, Cuba, in addition to places previously recorded.

The year 1907 marked the crossing of the Mississippi River into the State of Mississippi. There was a corresponding movement to the north, but none to the west. A very severe setback, caused by climatic conditions, occurred in the northern and western parts of the infested territory in November, 1907.

In 1908 the most noticeable advances were made into Mississippi and Arkansas. By this time a considerable part of the Mississippi Delta region of Louisiana had become infested.

In the spring of 1909 preparations were made for the establishment of a laboratory at Tallulah, La. The main object of this laboratory has been the accumulation of data concerning the local features of the weevil problem in the region where the greatest damage is certain to occur. Cold weather in the winter of 1908–9 again checked the boll weevil so completely that it did no appreciable damage in Oklahoma and the greater part of Texas during 1909. The checking of the insect was enhanced by the very unusual heat of July and August. However, there were enough weevils in the Red River Valley to give rise to a considerable movement into Arkansas and to a remarkable eastward movement in southern Mississippi which ended with a total advance of 120 miles eastward. This carried the insect to within 6 miles of the Alabama border. At the same time the decided climatic control of the season held the weevils in check in northern Louisiana so that the total advance in the Delta was little more than 20 miles northeastward. The year 1909 closed with an exceptionally cold December which greatly reduced the numbers of the weevil in extreme northern Louisiana and in Arkansas, Oklahoma, and northern Texas.

The winter of 1909–10 was probably more disastrous for the weevil than any it had previously experienced in this country. It was shown by examinations made in June and July, 1910, that the weevil had lost a very wide belt of territory in western Texas and that there was less than 1 per cent infestation in one-third of the infested region of Oklahoma and Texas. The reduction was also very pronounced in northern Louisiana and in the Mississippi Delta. In August it was found that there had been some recovery of lost territory, but there were still several thousand square miles of formerly infested territory in Oklahoma which the weevil had been unable to regain. There were slight gains in western Texas in the vicinity of Abilene late in the season and rather pronounced gains in the Delta region of Arkansas and in the hills of northern Mississippi and eastward through southern Mississippi and Alabama to the border of Florida. On account of the general scarcity of weevils the total amount of damage done during 1910 was less than had been experienced for several preceding years.

An early frost on October 29, 1910, throughout all but the coast regions of the infested territory, caused the death of all but a very small fraction of the fall-bred weevils, and consequently the season of 1911 started with a low infestation. The general defoliation by the leaf worm, however, reduced the available food supply and caused a general dispersion, which enabled the weevils to regain considerable lost ground in Texas and Oklahoma, to make remarkable gains in Arkansas, Mississippi, and Alabama, and to invade Florida.

DISTRIBUTION.

The territory covered by the boll weevil at the end of the year 1911 (see fig. 1) included the southeastern half of the cotton section of Texas, the southeastern corner of Oklahoma, the southern three-

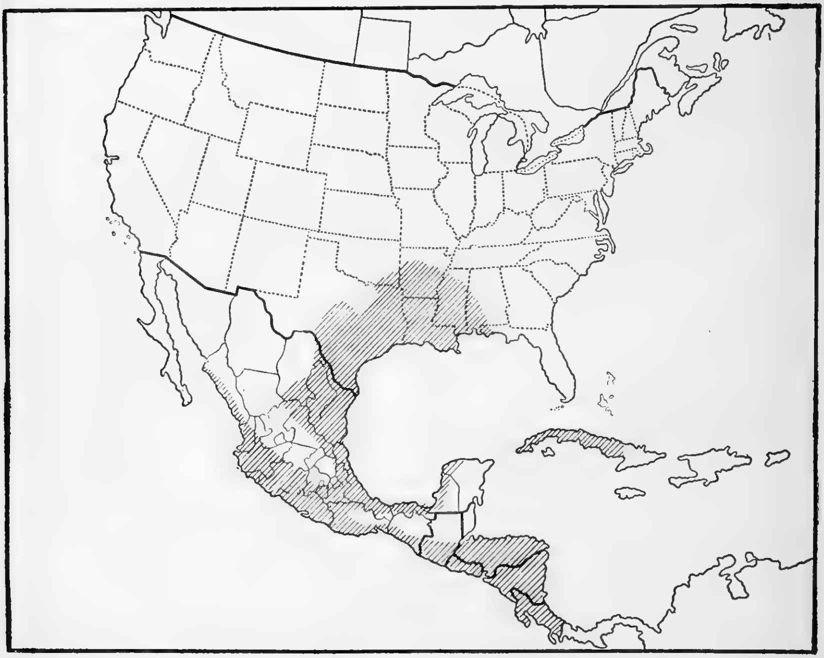


FIG. 1.—Map showing the distribution of the cotton-boll weevil on January 1, 1912. (Original.)

fourths of Arkansas, all of Louisiana, the southern three-fourths of Mississippi, the southwestern corner of Alabama, and the western portion of Florida. In addition to these States the weevil is found throughout Mexico in the cotton-growing region of both the Atlantic and Pacific coasts with the exception of certain mountain regions. Foremost among the excepted regions is that known as the Laguna district in the vicinity of Torreon, Mexico. The weevil has not been recorded from any part of Yucatan excepting the western coast, although it may occur on tree cottons throughout this region. It has not been recorded from British Honduras, but is known to occur throughout the cotton regions of Guatemala and in Costa Rica. There is little doubt but that it also extends into other Central American Republics, although no definite records have ever been

made. The five western States of Cuba are infested, and possibly the weevil is to be found throughout the entire island. It has not been found in any of the other West Indian Islands.

LOSSES DUE TO THE BOLL WEEVIL.[1]

Various estimates of the loss occasioned to cotton planters by the boll weevil have been made. In the nature of the case such estimates must be made upon data that are difficult to obtain and in the collection of which errors must inevitably occur. There is, of course, a general tendency to exaggerate agricultural losses as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas unfavorable weather at planting time, summer droughts, and heavy fall rains caused very light crops to be produced. Now, however, the tendency is everywhere to attribute all of the shortage to the weevil. Nevertheless, the pest is undoubtedly the most serious menace that the cotton planters of the South have ever been compelled to face, if not, indeed, the most serious danger that ever threatened any agricultural industry. It was generally considered, until the appearance of the pest in Texas, that there were no apparent difficulties to prevent an increase in cotton production that would keep up to the enlarging demand of the world until at least twice the present normal crop of about 12,000,000 bales should be produced. Now, however, in the opinion of most authorities, the weevil has made this possibility somewhat doubtful, although the first fears entertained in many localities that the cultivation of cotton would have to be abandoned have generally been given up. An especially unfavorable feature of the problem is in the fact that the weevil reached Texas at what would have been, from other considerations, the most critical time in the history of the production of the staple in the State. The natural fertility of the cotton lands had been so great that planters had neglected such matters as seed selection, varieties, fertilizers, and rotation, that must eventually receive consideration in any cotton-producing country. In general, the only seed used was from the crop of the preceding year, unselected, and of absolutely unknown variety, and the use of fertilizers had not been practiced at all. Although it is by no means true that the fertility of the soil had been exhausted, nevertheless, on many of the older plantations in Texas the continuous planting of cotton with a run-down condition of the seed combined to make a change necessary in order that the industry might be continued profitably.

In 1905 Prof. E. D. Sanderson[2] made a very careful estimate of the damage done by the boll weevil in Texas for the six years ending with 1904. During this period he found that there had been an average annual decrease due to the boll weevil of 43 per cent, amounting to 0.182 bale per acre a year in the infected territory.

Prof. Sanderson found that in 1899 the 18 counties infested at that time showed a decrease of 0.135 bale per acre, of which it was considered that 150,000 bales were chargeable to the weevil. In 1900 the great storm of September complicated matters so that no reliable estimate of injury could be made. In 1901 the general conditions

[1] The following paragraph is modified from Bul. No. 51, Bureau of Entomology, pp. 21-25.
[2] The Boll Weevil and Cotton Crop of Texas, published by the Texas Department of Agriculture.

throughout the State were unfavorable to the cotton crop, resulting in a reduction of 0.05 bale per acre for the uninfested portion of the State. The weevil loss was estimated at 100,920 bales. In 1902 the 32 counties infested produced 0.28 bale per acre. The loss chargeable to the boll weevil was 200,000 bales. In 1903 the 49 counties infested yielded 0.23 bale per acre, as against an average of 0.43 bale during years previous to infestation, which was interpreted to show a loss of 500,000 bales due to the weevil. In 1904, 69 counties were infested. These showed a loss of 0.22 bale per acre. This meant, after deducting the losses due to the bollworm and other causes, a loss of 550,000 bales due to the boll weevil. In these estimates the losses for the period from 1899 to 1904 amounted to 1,725,000 bales.

The weevil was in Texas from 1899 to 1904, but had not caused any appreciable damage in Louisiana during that period. The statistics of production and acreage of the two States for these years show clearly the effect of the weevil on the crop.

TABLE I.—*Comparison of cotton production and acreage in Texas and Louisiana in equivalents of 500-pound bales.*

Year.	Texas.		Louisiana.	
	Acreage.	Crop.	Acreage.	Crop.
	Acres.	*Bales.*	*Acres.*	*Bales.*
1899	6,642,309	2,609,018	1,179,156	700,352
1900	7,041,000	3,438,386	1,285,000	705,767
1901	7,745,100	2,502,166	1,400,650	840,476
1902	8,006,546	2,498,013	1,662,567	882,073
1903	8,129,300	2,471,081	1,709,200	824,965
1904	8,704,000	3,030,433	1,940,000	893,193

It will be seen that while the acreage in Texas and Louisiana increased at about the same proportion the crop in Texas decreased annually for the six years ending with 1904 (with two exceptions—1900 and 1904), while the crop in Louisiana increased annually (with one inconsiderable exception, in 1903). That the boll weevil prevented Texas from keeping pace with Louisiana during this period will be admitted by all. The exceptional years, 1900 and 1904, in which the production in Texas did not decrease, were those in which the conditions for the cotton plant were unusually favorable. Moreover, it is to be noted that in the first of these two years the pest had not reached far into the most productive counties.

Further indications of the amount of weevil damage are available from the statistics of production per acre, as shown by Table II:

TABLE II.—*Average yield per acre of cotton by five-year periods in 500-pound bales.*

Years.	Texas.	Louisiana.	Arkansas.	Oklahoma.	Mississippi.
	Bale.	*Bale.*	*Bale.*	*Bale.*	*Bale.*
1879	0.39	0.58	0.58	0.48	0.45
1889	.37	.51	.40	.48	.40
1893–1897	[1] .38	.52	.45	.52	.43
1898–1902	[1] .39	.52	.45	.47	.40
1903–1907	[1] .34	[1] .49	[1] .40	[1] .47	.44
1908–1910	[1] .32	[1] .29	[1] .37	[1] .35	[1] .40

[1] During these periods the weevil has caused more or less damage to the crop.

At 13 cents a pound for lint (average price in 1909) the 1908–1910 average yields would mean an average loss from the average yield of 1893–1897 of the following amounts per acre:

Texas	$3.90
Louisiana	15.25
Arkansas	5.20
Oklahoma	11.05
Mississippi	1.95

Messrs. Norden & Co., of New York, have made a conservative estimate of the average annual loss in the various States, as follows:

	Per cent.
Texas, about	15
Louisiana	15
Arkansas	15
Mississippi	21

The Bureau of Statistics of this department estimated the losses to the cotton crop in 1909 from various causes as shown below:[1]

TABLE III.—*Amount of injury to cotton crop of 1909 due to various causes.*

State.	Loss in seed cotton per acre from—						
	Climatic conditions.	Boll weevil.	Boll-worm.	Other insects.	Plant diseases.	Miscellaneous causes.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Arkansas	112.2	21.5	2.5	0.7	14.4	0.7	152.0
Louisiana	38.8	148.8	8.5	1.3	11.0	1.4	209.8
Mississippi	103.3	14.1	8.0	0.7	18.8	3.1	148.0
Oklahoma	147.3	11.0	3.7	0.4	2.2	3.4	168.0
Texas	100.4	37.6	8.7	0.0	7.7	0.6	155.0
Average of infested region	100.4	46.6	6.2	0.6	10.8	1.8	166.4

According to this estimate, the boll weevil was responsible for 28 per cent of the loss in the five infested States and 14.9 per cent of the loss in the United States. This loss was estimated as 1,267,000 bales of 500 pounds, which, at the current price of cotton in 1909, would be worth $88,056,500. Although the estimate of the Bureau of Statistics may be high, it was based upon the reports of numerous trained observers throughout the infested territory.

Frequently misconceptions arise regarding the manner in which the weevil has affected cotton production in Texas. This is due to the fact that the total crop of the State has been maintained more or less regularly since the advent of the pest. In order to obtain exact information on this point we must examine the statistics of production in different parts of the State.[2]

It is necessary to divide the State into three areas. These are eastern, central, and western Texas. The divisions are made in accordance with variations in normal annual precipitation and other factors. Eastern Texas as used in this bulletin is bounded on the west by a line running practically north and south from the western

[1] Crop Reporter, vol. 12, No. 12, p. 94, December, 1910.
[2] The following four paragraphs and table are extracted, with a few modifications, from Circular No. 122, Bureau of Entomology, pp. 5–8.

line of Lamar County to the western line of Brazoria County. In this region the rainfall is 45 inches per year or more. It comprises the counties listed below.[1] Practically the whole area is covered with forests. It covers 40,180 square miles. Central Texas comprises a broad belt from the Gulf to the Red River, beginning on the west with the limit of the belt of 32 inches normal annual rainfall, and extends eastward to the line just described as defining the western boundary of the eastern Texas area. Central Texas consists of 45 counties[2] and comprises 38,868 square miles.

It is for the most part prairie country, although there are wooded valleys and occasional strips of timbered uplands. Western Texas comprises the remainder of Texas, beginning with the line marking the western limit of the area of 32 inches normal annual precipitation. It is largely a prairie region, though wooded valleys are numerous. Another factor in differentiating western Texas from central Texas is the increased elevation.

A careful study has been made of the manner in which the weevil has affected the production of cotton in the three regions mentioned. Use has been made of the Census records of production from 1899 to 1910, a period of 12 years, as shown in Table IV:

TABLE IV.—*Eastern, central, and western Texas cotton production compared, 1899–1910 from United States Census.*

[500-pound bales.]

Years.	Eastern.		Central.		Western.[3]	
	Bales.	Proportion of Texas crop.	Bales.	Proportion of Texas crop.	Bales.	Proportion of Texas crop.
		Per cent.		*Per cent.*		*Per cent.*
1899	637,872	22.44	1,633,618	62.61	337,528	12.94
1900	811,413	23.59	1,892,669	55.04	734,304	21.36
1901	633,620	25.32	1,448,872	57.90	419,674	16.77
1902	736,660	29.48	1,332,487	53.34	428,866	17.17
1903	545,288	22.06	1,242,654	50.28	683,139	27.64
Average, 1899–1903	672,970	24.88	1,510,060	55.85	520,702	19.26
1904	720,671	22.91	1,700,224	54.15	724,475	23.07
1905	329,523	12.96	1,414,115	55.63	798,294	31.40
1906	672,497	16.11	2,213,863	53.03	1,287,846	30.85
1907	343,328	14.92	1,218,143	52.95	738,708	32.11
1908	515,038	13.50	1,980,766	50.60	1,318,681	33.68
1909	474,311	18.80	1,362,096	53.99	686,404	27.20
1910	645,158	21.15	1,677,688	55.02	726,553	23.83
Average, 1904–1910	528,647	17.19	1,652,414	53.62	797,280	28.88

In eastern Texas the production for five years ending with 1903 averaged 24 per cent of the total crop of Texas. During the same series of five years western Texas averaged 19 per cent of the total

[1] Red River, Bowie, Franklin, Titus, Morris, Cass, Wood, Camp, Upshur, Marion, Harrison, Smith, Gregg, Cherokee, Rusk, Panola, Nacogdoches, Shelby, San Augustine, Sabine, Angelina, Trinity, San Jacinto, Polk, Tyler, Jasper, Newton, Liberty, Hardin, Orange, Jefferson, Chambers Galveston, Lamar, Delta, Hopkins, Rains, Van Zandt, Henderson, Freestone, Anderson, Leon, Houston, Madison, Waller, Grimes, Walker, Montgomery, Harris, Fort Bend, and Brazoria.

[2] Central Texas counties: Cooke, Grayson, Fannin, Denton, Collin, Hunt, Tarrant, Dallas, Rockwall, Kaufman, Johnson, Ellis, Bosque, Hill, Navarro, McLennan, Limestone, Bell, Falls, Williamson, Milam, Robertson, Brazos, Travis, Lee, Burleson, Washington, Hays, Bastrop, Caldwell, Fayette, Colorado, Austin, Guadalupe, Gonzales, Lavaca, Wharton, Dewitt, Goliad, Victoria, Jackson, Refugio, Calhoun, Matagorda, and Aransas.

[3] Including counties grouped by Census under "All other."

crop. For the seven years ending with 1910 the eastern Texas production dropped to 17 per cent of the total crop of the State, while the production in western Texas advanced to 28 per cent of the total crop of the State. In other words, the portion of the Texas crop produced in one area has decreased 21 per cent, and in the other it has increased 53 per cent. This increase in the west, where the dry climate reduces the boll-weevil injury, served to offset the loss in eastern Texas and thus accounts to a great extent for the fact that the total crop of the State has not fallen off.

Mr. F. W. Gist, of the Bureau of Statistics of this department, has made a very careful study to determine the center of cotton production in Texas for each year from 1899 to 1908. As would be supposed from the figures that have been given, it was found by Mr. Gist that the center of production had moved considerably to the westward. In fact, this center moved from 30.78 miles east of the ninety-seventh meridian in 1899 to 19.14 miles west of this meridian in 1908. This was a westward movement of practically 50 miles. The center of production in 1899 was on a line passing north and south through the eastern Cortion of Grayson pounty, in Texas. In 1908 the center had moved to a line passing parallel with the other through the western portion of Cooke County, in Texas. These statements may be illustrated by the following map (fig. 2).

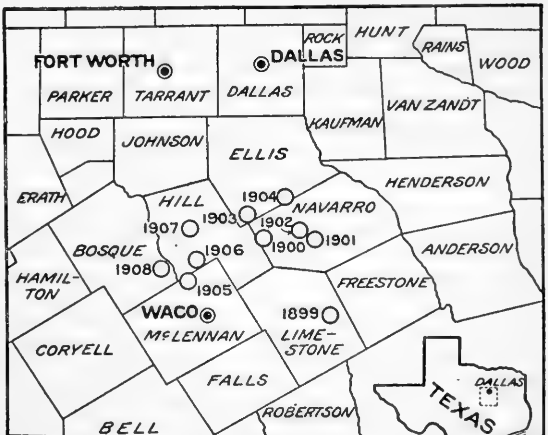


FIG. 2.—Map of portion of Texas, showing movement of the center of cotton production westward. (Original.)

The statistics which have been given show the entire fallacy of attempting to estimate the seriousness of the boll-weevil problem by considering only the total crop which has been produced in Texas for some years past. It is absolutely necessary in estimating the damage that is likely to be done in any certain region to find the portion of Texas in which the climatic and other conditions are most like those in the region that is being considered. In Texas there are several very distinct boll-weevil problems due to local conditions, exactly as there are numbers of distinct agricultural provinces. The future of the boll weevil in the eastern part of the United States can not be foretold unless the manner in which the insect has affected the portion of Texas which is most like the eastern part of the belt is considered. An investigation of this matter will show that the eastern part of Texas is the only part of the State which is like the eastern portion of the cotton belt in the climatic and other features which react upon the boll weevil. This is especially the case with

reference to precipitation, the presence of timber, and temperature. It is clear, therefore, that the only criterion by which to judge the future damage of the weevil is the effect it has exerted on production in eastern Texas, where, as has been shown, there has been a considerable decrease in production.

INDIRECT LOSSES CAUSED BY THE BOLL WEEVIL.

The foregoing discussion has dealt altogether with the direct losses caused by the boll weevil, but it is to be noted that there are certain indirect losses which must be considered. It is not alone the farmers who are affected. The reduction in the size of the cotton crop immediately affects the ginning and oil-mill industries in which large amounts of money are invested. The railroads, banks, and merchants are also concerned. In fact, the disturbance extends throughout the community. In the case of many parishes in Louisiana one of the first results of the invasion of the boll weevil has been the reduction in the assessed valuation of farm lands. In all regions, for at least a short time, the price of farm properties has been reduced. Likewise in many localities the invasion of the insect has caused the exodus of large numbers of tenants and even of landlords. In the former case landowners have found themselves without the labor to run their places. Losses due to such disturbances can not be estimated, but it is safe to say that they reach an aggregate amount at least equal to the direct losses which are caused.

COMPENSATIONS FOR LOSSES CAUSED BY THE BOLL WEEVIL.

In spite of the great losses caused by the boll weevil it must be recognized that certain compensations are returned. The insect forces a diversification of crops. There is no doubt that there is a tendency to place too much dependence in the South upon the cotton crop. When the ravages of the boll weevil reduce the size of this crop materially or make production of a cotton crop hazardous, the farmers must change their system of cropping materially. This results directly in diversification and animal husbandry, and thus tends toward a more logical and profitable system of agriculture. Of course it would be much better if this change could be brought about by less revolutionary means and with less loss than is caused by the boll weevil. The tendency for many years has been toward diversification, which was certain to come in time. The boll weevil has undoubtedly hastened it and has thus in a broad sense offset, to a certain degree, some of the direct losses which it has caused. It is to be noted, however, that in many cases this forced and, in one sense, premature diversification of crops has resulted disastrously. In some localities extensive and rapid growth has taken place in fruit raising and market gardening. In some of these instances the new industries have developed with abnormal rapidity and without the proper foundation. This was the case in extensive plantings of potatoes made in 1909 by the cotton planters of Avoyelles Parish, La. The result has been that unless carefully managed the new lines of farming have failed and there has been a tendency to return to the cultivation of cotton.

The boll weevil also tends to eliminate the indifferent and unprogressive farmer. He is driven either to the city or to some other locality.

In this way the weevil works toward the production of a better class of farmers. Of course, no community favors a reduction in the number of inhabitants. It would prefer that the inefficient remain and be improved by education or otherwise. This effect of the invasion of the boll weevil, therefore, can not generally be looked upon as a benefit.

PROSPECTS.

The rapid spread of the boll weevil in the past few years and its apparent adaptability to most of the conditions prevalent in the cotton region of the United States indicate that it will ultimately be able to exist in all except the semiarid portions of the entire cotton-growing country. In order better to estimate the probable movement in the future, we present Table V to illustrate its progress since the year 1892:

TABLE V.—*Annual movement of the boll weevil in the United States.*

Year.	Weevil advance.							Total movement.	Total area infested.
	Texas.	Louisiana.	Oklahoma.	Arkansas.	Mississippi.	Alabama.	Florida.		
	Sq. mi.	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*
1892	1,400							1,400	1,400
1893	7,400							7,400	8,800
1894	10,300							10,300	19,100
1895	7,900							7,900	27,000
1896	[1] 7,300							[1] 7,300	19,700
1897	9,600							9,600	29,300
1898	7,200							7,200	36,500
1899	6,600							6,600	43,100
1900	6,600							6,600	49,700
1901	6,700							6,700	56,400
1902	11,600							11,600	68,000
1903	11,700	300						12,000	80,000
1904	39,600	7,300						46,900	126,900
1905	17,000	3,400						20,400	147,300
1906	22,600	9,300	4,200	500				36,600	183,900
1907		5,000	8,200	7,800	500			21,500	205,400
1908		5,700	1,500	6,500	4,800			18,500	223,900
1909		9,800	1,900	7,500	10,700			29,900	253,800
1910	1,400		[1] 6,500	1,900	13,500	3,900		14,200	268,000
1911	[1] 21,000		[1] 3,000	9,700	11,000	5,400	1,400	3,500	271,500
Total	139,300	40,800	6,300	31,900	40,500	9,300	1,400	271,500	

[1] These figures indicate losses instead of gains.

A summary of Table V in three-year periods is given below:

TABLE VI.—*Average annual rate of boll-weevil movement.*

Three-year periods.	Total movement.	Yearly average.	Average of averages.
	Sq. miles.	*Sq. miles.*	*Sq. miles.*
1892–1894	19,100	6,366	
1895–1897	10,200	3,400	
1898–1900	20,400	6,800	5,522
1901–1903	30,300	10,100	
1904–1906	103,900	34,633	
1907–1909	69,900	23,300	22,677
	253,800		14,099

At the end of 1910 the total area infested was 268,000 square miles, a net gain of 14,200 square miles over 1909. Including the year 1910, the average rate of movement in the United States beginning with

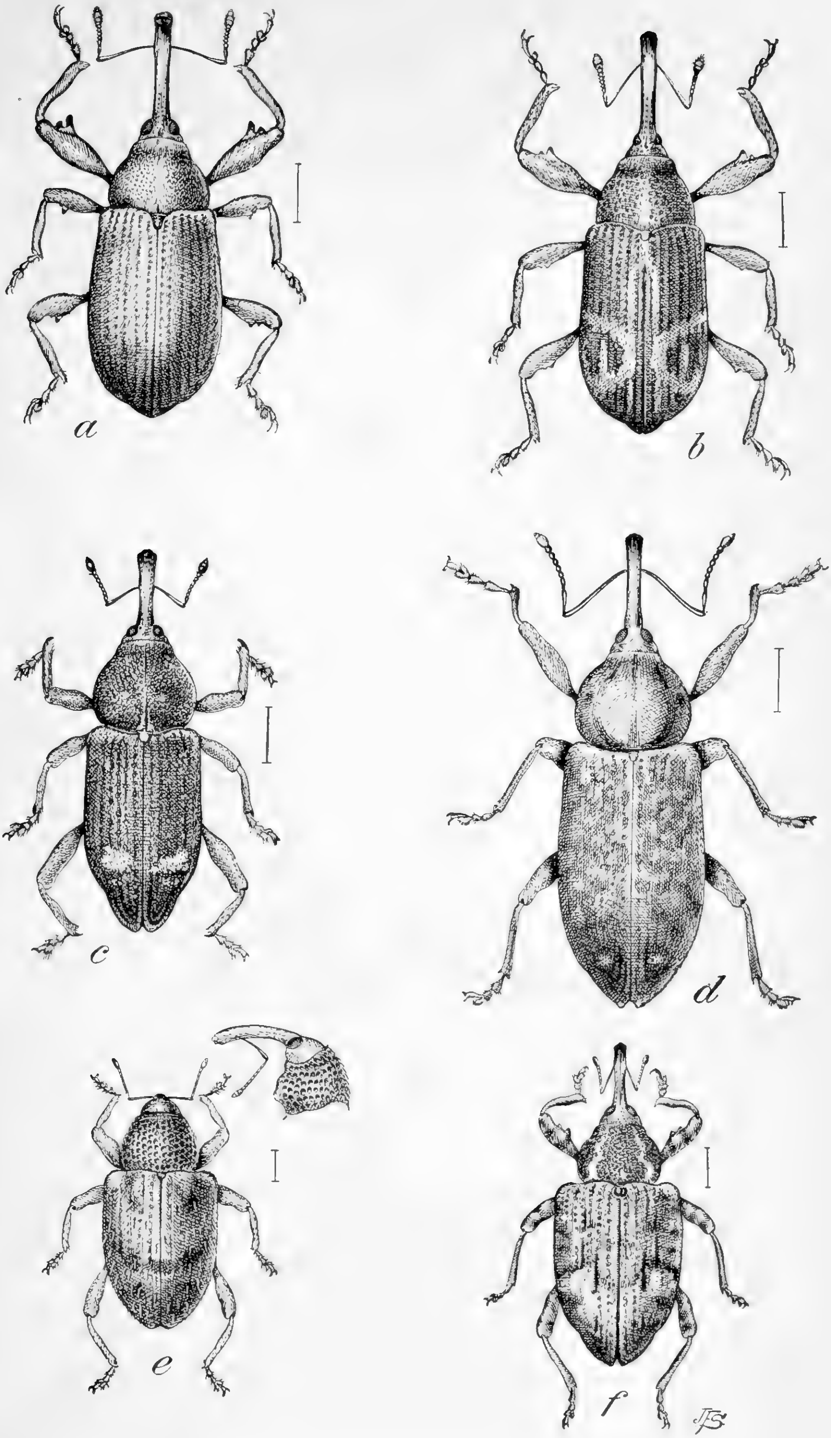
1904 has been 27,000 square miles a year, with 402,000 square miles of cotton-producing area yet free. It is therefore reasonable to estimate that it will take at least 15 years before the entire cotton region of this country can become infested.

It is evident, however, that the weevil will find certain definite checks in the cotton-growing regions of this country. Among the more important of these checks are (1) dryness, (2) low winter temperatures, (3) altitude, and (4) such combinations of these factors as tend to form definite life zones. The possible effects of these factors will be discussed separately.

Dryness is the most important check the boll weevil experiences. The insect has repeatedly advanced into western Texas, but has invariably been prevented from gaining a foothold by the dry climate of that region. Occasional wet seasons have resulted in apparent gains in that quarter, but they have been nullified by the recurrence of normal years. The extremely dry conditions in Texas, Oklahoma, and Arkansas during the summers of 1909 and 1910 had a remarkable effect upon the weevil. Combined with the very severe winters, these dry summers practically excluded the weevils from the western half of the infested region of Texas and most of the infested region in Oklahoma. The damage done in these regions for two seasons has occurred only after the breaking of the intense summer heat. The occasional occurrence of a dry summer, however, does not give any promise of future immunity from the boll weevil, because its tendency to disperse in the fall in all directions enables it to regain any ground which it might lose during such a season. It is also important to note that the practice of irrigation in dry regions may counteract the effects of the lack of precipitation and enable the weevil not only to maintain itself, but to cause considerable damage.

The low temperatures of the winters of 1907, 1908, and 1909 had a very pronounced effect upon the numbers of the weevil in the following years. An analysis of the minimum temperatures reached in the regions where the weevils were most affected indicates that such control was the result of a temperature of 12° above zero. In some places where this temperature was reached there were earlier low temperatures which may have forced the weevils into considerably heavier shelter than they would have selected normally. This apparently enabled the weevils to survive even a temperature of 5° above zero. Although the information at hand is rather incomplete, we can nevertheless hold out some hope that regions having a minimum temperature of from 5° to 10° above zero will have little trouble from the boll weevil. In later sections of this bulletin we will show how even higher minimum temperatures can greatly reduce the weevil damage of the following year. The weakness of predictions of this kind is that they do not take into account the fact that the weevil is rapidly adjusting itself to changed conditions and that eventually the result of natural selection will be a class of weevils which can withstand greater vicissitudes than those of the present.

The extremely slow progress into western Texas might be explained on the basis of altitudes. So far, the weevil has not established itself at an altitude above 2,000 feet. It may be possible that this altitude is its extreme limit. Again, there is danger in this assumption,



THE BOLL WEEVIL AND INSECTS OFTEN MISTAKEN FOR IT.

a, The cotton boll weevil, *Anthonomus grandis;* *b*, the mallow weevil, *Anthonomus fulvus;* *c*, the southern pine weevil, *Pissodes nemorensis;* *d*, the cottonwood-flower weevil, *Dorytomus mucidus;* *e*, *Conotrachelus erinaceus;* *f*, the pecan gall weevil, *Conotrachelus elegans.* (Original.)

because the boll weevil has shown considerable adaptability in the past and may be able to adapt itself to higher altitudes than it has yet reached.

With regard to the possible relation between life zones and the distribution of the weevil it is to be said that at present the infested territory includes the tropical regions of Cuba, Central America, and Texas, and a considerable part of the Austroriparian Zone of the Lower Austral Region in the other Southern States. It is interesting to note that the weevil has not yet succeeded in establishing itself in the Upper Sonoran Zone of the Upper Austral Region of either Mexico or western Texas. It has invaded, or at least surrounded, two isolated areas of the Carolinian Zone of the Upper Austral Region in Oklahoma and Arkansas. Considerable cotton is grown in western Texas, in the Upper Sonoran Zone. There also exist in Arkansas, southern Missouri, Tennessee, northern Georgia, northern South Carolina, western North Carolina, and Virginia large regions of cotton-producing territory included in the Carolinian Zone. It is possible that the boll weevil will be unable to establish itself permanently beyond the limits of the Lower Austral Zone and this would exclude it from the regions just mentioned.

As a matter of fact, the effects of climatic conditions upon the weevil are so powerful that there may be occasional diminution in the serious attacks from the insect in the moist regions, such as was experienced in the summer of 1911. The season of 1911 was unusual in Louisiana and Mississippi, starting with severe cold in January, which cut down the emergence from hibernation to 0.5 per cent, and continuing with a very unusual drought. Such conditions are not often experienced, and we may usually expect severe attack by the weevil in southern Louisiana and the Delta of Mississippi.

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

The anticipated appearance of a serious pest such as the boll weevil in new regions causes greater attention to be given to the insects found in the cotton fields. Many planters notice common native insects which appear to answer the description of the boll weevil. The result of such mistaken identifications is generally a local panic. On account of the difficulty of distinguishing the boll weevil from a large number of related insects, we advise that whenever a planter discovers an insect which he suspects to be the boll weevil he send it either to the State entomologist or to the Bureau of Entomology and receive authoritative information.[1]

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[1] Addresses of officials who will give authentic determinations of the boll weevil:
Alabama.—W. E. Hinds, Auburn.
Arkansas.—Paul Hayhurst, Fayetteville.
Florida.—E. W. Berger, Gainesville.
Georgia.—E. L. Worsham, Atlanta.
Louisiana.—J. B. Garrett, Baton Rouge.
Mississippi.—R. W. Harned, Agricultural College.
North Carolina.—Franklin Sherman, jr., Raleigh.
Oklahoma.—C. E. Sanborn, Stillwater.
South Carolina.—A. F. Conradi, Clemson College.
Tennessee.—G. M. Bentley, Knoxville.
Texas.—Wilmon Newell, College Station. Ernest Scholl, Austin, Department of Agriculture. W. D. Hunter, Bureau of Entomology, Dallas.
Virginia.—E. A. Back, Blacksburg.

Many of the weeds in the vicinity of the cotton fields are attacked by different species of weevils which may in some respects resemble the boll weevil. Some of these weevils are of a general dark color and have beaks with which to puncture their food plants. On close observation it will be found that the weevils which are discovered on other weeds are breeding in those weeds. They are not the boll weevils and will not attack the cotton. Many of these native weevils are also found on the cotton plants at the nectar which is produced by the squares, blooms, and leaves. These weevils simply visit the cotton plants in order to feed upon this nectar and do not injure the plant in any way. The following list contains the names and references to the habits of some of the most common weevils which occur in and about cotton fields:

Insects often mistaken for the boll weevil (*Anthonomus grandis* Boh.). (Pl. II, *a*.)

Weevil.	Attacks.
Anthonomus albopilosus Dietz	Seed pods of wild sage (Croton).
Anthonomus eugenii Cano	Pepper pods.
Anthonomus fulvus Le C. (Pl. II, *b*)	Purple mallow buds.
Anthonomus signatus Say	Blackberry, dewberry, and strawberry buds.
Anthribus cornutus Say	Cotton stems.
Aræcerus fasciculatus DeG	China-berries, coffee beans, and old cotton bolls.
Balaninus nasicus Say	Acorns.
Balaninus victoriensis Chitt	Live oak acorns.
Baris striata Say	Roots of ragweed (Ambrosia).
Baris transversa Say	Roots of cockle-bur (Xanthium).
Chalcodermus æneus Boh	Cowpea pods.
Conotrachelus elegans Say (Pl. II, *f*)	Galls and nuts of pecans.
Conotrachelus erinaceus (Pl. II, *e*)	Habits unknown.
Conotrachelus leucophæatus Fab	Stems of careless weed (Euphorbia).
Conotrachelus naso LeC	Acorns.
Conotrachelus nenuphar Hbst	Fruit of plums and peaches.
Desmoris constrictus Say	Seed of sunflower (Helianthus).
Desmoris scapalis LeC	Flower heads of broad-leaved gum plant (Sideranthus).
Dorytomus mucidus Le C. (Pl. II, *d*)	Cottonwood catkins.
Epicærus imbricatus Say	Habits unknown, adult feeds on foliage.
Geræus penicellus Hbst	Habits unknown, visits cotton nectar.
Geræus picumnus Hbst	Habits unknown, visits cotton nectar.
Gerstæckeria nobilis LeC	Joints of prickly pear.
Hylobius pales Hbst	Pine bark.
Lixus scrobicollis Boh	Stems of ragweed (Ambrosia).
Pachylobius picivorus Germ	Pine branches and bark.
Pissodes nemorensis Germ. (Pl. II, *c*)	Pine branches and bark.
Rhynchites mexicanus Gyll	Rosebuds.
Rhyssematus palmacollis Say	Morning-glory pods.
Trichobaris mucorea LeC	Tobacco stalks.
Trichobaris texana LeC	Spanish thistle stalks. (*Solanum rostratum*).
Tychius sordidus LeC	Pods of false indigo (Baptisia).

Many other insects are sometimes mistaken for the boll weevil. This list includes only the species which are more or lesss closely allied to that insect and consequently more commonly confused with it.

FOOD PLANTS OF THE BOLL WEEVIL.[1]

The careful investigations of Mr. E. A. Schwarz in Guatemala, Mexico, and Cuba have convinced him that the original food plants of the boll weevil are the tree cottons of those countries. One of these species has the seeds adhering together in a mass and is called "kidney" cotton from the shape of this mass. The other has seeds separated as in Upland cotton of the United States and is probably the *Gossypium brasiliense* of botanists. The former appears to be the more ancient form and presumably is the species upon which the weevil originally subsisted. Cotton is now rarely cultivated in Cuba, but the practically wild tree cottons are found throughout the island, and on these the boll weevil is generally to be found, although in very small numbers. There are, however, frequently found throughout the island isolated plants which are not infested. The areas of cultivation of cotton in Guatemala are extremely isolated, but the presence of tree cotton perpetuates the weevil and gives it a rather general distribution. In Mexico the principal regions of cotton growth are represented by narrow belts along the two coasts and a large area in the north-central portion known as the "Laguna." Tree cotton probably serves to continue the boll weevil's activity in many parts of Mexico where cotton is not cultivated. It is impossible to decide whether the boll weevil originated in Cuba or in Central America, as it occurs in practically the same condition in both places. It is, however, practically certain that the insect has attacked the cotton plant from antiquity. In fact, there is nothing to indicate that it ever had any other food plant.

The question of the possibility that the boll weevil may feed upon some plant other than cotton is one of importance. As an illustration we may state that as long as cotton is extensively produced in any given region there is comparatively little danger, but if a certain region should forego the planting of cotton for a period of years in order to escape boll-weevil injury and then resume its cultivation, it is apparent that all efforts would fail if the boll weevil could in the meanwhile exist on other native plants.

It is a well-known fact that insects which have few food plants usually confine their attacks to closely related plants belonging to the same botanical family or even genus. The native plants most closely allied to cotton in the regions so far infested are the various species of Hibiscus and the trailing mallows of the genus Callirrhoe. Careful tests have been made with these plants and with many unrelated plants, both as to their powers of sustaining life and the inducements offered for oviposition. Six species of Hibiscus, namely, *esculentus, vesicarius, manihot, moscheutos, militaris,* and *africanus,* have been tested to ascertain how long the weevil could live on them and whether it would oviposit in the fruit. In experiments conducted by Dr. W. E. Hinds hibernated weevils starved in an average time of about four days with leaves of either *Hibiscus esculentus* or *H. militaris.* Weevils

[1] There has recently been discovered by Prof. C. H. T. Townsend another serious cotton pest, *Anthonomus vestitus* Boheman, which we may designate as the Peruvian cotton square weevil, as it is not at present known outside of Peru and Ecuador. Prof. C. S. Banks has also discovered in the Philippine Islands a weevil feeding in cotton flowers which may be known as the Philippine cotton flower weevil. This species has been described as *Ecthetopyga gossypii* Pierce. The coffee-bean weevil, *Aræcerus fasciculatus* DeGeer, frequently breeds in old dried cotton bolls, and the cowpea pod weevil, *Chalcodermus æneus* Boheman, breeds occasionally in fresh cotton squares in fields of cotton following cowpeas. On account of the existence of these other square and boll weevils it is still necessary to retain the original name Mexican cotton boll weevil for *Anthonomus grandis* Boheman.

of the first generation which had fed upon no cotton were placed upon *Hibiscus militaris*, and these starved within an average of three or four days. The first-generation weevils which had fed for a few days on squares were placed upon leaves, buds, and seed pods of *Hibiscus vesicarius*. Though they fed a little, all starved in an average of about five days. A lot of first-generation weevils, fed first for several days with squares, were given leaves, buds, and seed pods of okra More feeding was done by this lot than by any other, all parts being slightly attacked. These weevils lived for an average of seven days. In experiments conducted independently by Messrs. Tucker and Jones at Alexandria and Shreveport, La., and Dallas, Tex., with *H. moschuetos*, *H. militaris*, and *H. africanus*, weevils were found to feed slightly on the pods, and fertile eggs were also found on the outside of the pods, but none were ever placed within.

No results whatever were obtained by experiments with a species of Abutilon. In an experiment with hollyhock (*Althæa* sp.) three weevils lived an average of six days. In experiments by Mr. W. W. Yothers with buds of *Callirrhoe involucrata*, 42 weevils were fed for an average of 5.6 days, the maximum length of life being 11 days. These records show that the weevils may possibly be able to feed for a few days on some of the other malvaceous plants and that they may even be forced to oviposit, but that under present conditions they are unable to sustain life or to reproduce in these plants. The maximum length of life which they have been able to live on any of these plants is hardly greater than they could live with sweetened water (see Table XIII).

Unsuccessful attempts were made to cause the weevil to feed upon sunflower (*Helianthus annuus*), bindweed (*Convolvulus repens*), the pigweeds (*Amaranthus hybridus* and *A. spinosus*), the ragweed (*Ambrosia psilostachya*), and various other species of weeds and grasses which occur more or less frequently around cotton fields.

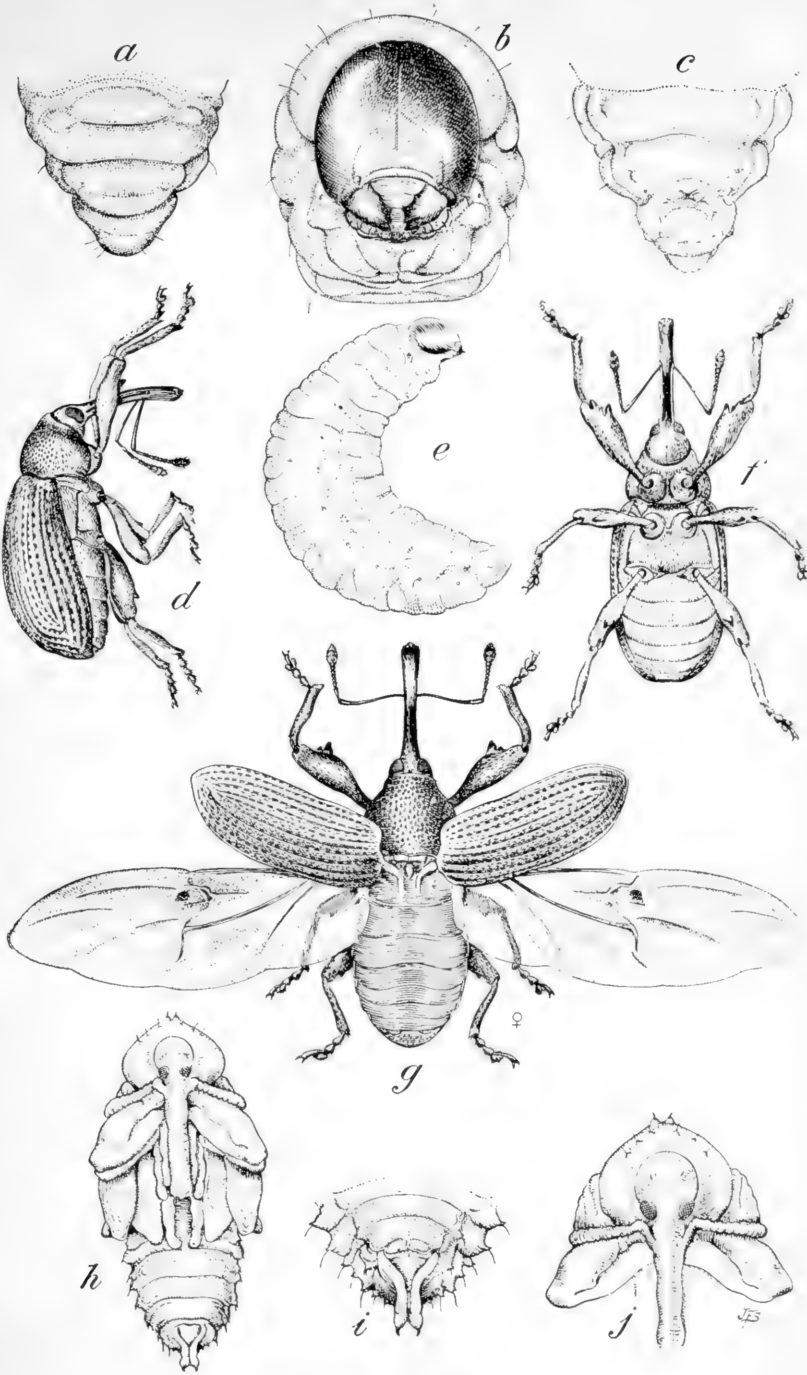
Throughout the investigations of Prof. C. H. T. Townsend in southern Texas and Mexico and of Mr. E. A. Schwarz in Texas, Cuba, Mexico, and Guatemala, and the observations made by the writers and their associates in all the infested region of the United States, every plant closely related to cotton has been most carefully watched. The uniform failure to find the weevil feeding upon any other plant makes it practically certain that cotton is its only food plant. Of course, the insect sometimes alights upon other plants, as it does upon fence posts and other objects. Such occurrences are altogether accidental. Frequent reports of the finding of the weevil breeding in other plants are due to mistaking some other insect for the enemy of cotton.

LIFE HISTORY.

SUMMARY.[1]

The egg is deposited by the female weevil in a cavity formed by eating into a cotton square or boll. The egg hatches in a few days and the footless grub begins to feed, making a larger place for itself as it grows. During the course of its growth the larva sheds its skin at least three times, the third molt being at the formation of the pupa, which after a few days sheds its skin, whereupon the transformation

[1] Extract from Bulletin 51, Bureau of Entomology, pp. 30, 31.



ANATOMICAL STRUCTURE OF THE BOLL WEEVIL.

a, Dorsal view of anal segments of larva; *b*, front view of head and anterior segments of larva; *c*, ventral view of anal segments of larva; *d*, lateral view of adult; *e*, lateral view of larva; *f*, ventral view of adult; *g*, dorsal view of adult with wings spread; *h*, ventral view of pupa; *i*, ventral view of anal segments of pupa; *j*, ventral view of anterior portion of pupa. (Original.)

becomes completed. These immature stages require on the average between two and three weeks. A further period of feeding equal to about one-third of the preceding developmental period is required to perfect sexual maturity so that reproduction may begin.

DESCRIPTION.

THE EGG.[1]

The egg of the boll weevil is an unfamiliar object even to many who are thoroughly familiar with the succeeding stages of the insect. If laid upon the exterior of either square or boll, it would be fairly conspicuous on account of its pearly white color. Measurements show that it is, on the average, about 0.8 mm. long by 0.5 mm. wide. Its form is regularly elliptical, but both form and size vary somewhat. Some eggs are considerably longer and more slender than the average, while others are ovoid in shape. The shape may be influenced by varying conditions of pressure in deposition and the shape of the cavity in which it is placed. The soft and delicate membrane forming the outer covering of the egg shows no noticeable markings, but is quite tough and allows a considerable change in form. Were the eggs deposited externally they would doubtless prove attractive to some egg parasite as well as to many predatory insect enemies. Furthermore, the density of the membranes would be insufficient to protect the egg from rapid drying or the effects of sudden changes in temperature. All these dangers the female weevil avoids by placing the eggs deeply within the tissue of the squares or bolls upon which she feeds. As a rule, the cavities which receive eggs are especially prepared therefor and not primarily for obtaining food. Buried among the immature anthers of a square or on the inner side of one carpel of a boll, as they frequently are, weevil eggs become very inconspicuous objects and are found only after careful search.

THE LARVA.[2]

(Pl. III, *a*, *b*, *c*, *e*.)

The young larva, upon hatching from the egg, is a delicate, white, legless grub of about 1 mm. ($\frac{1}{25}$ inch) in length. Except for the brown head and dark brown mandibles the young larva is at first as inconspicuous as the egg from which it came. As it feeds and grows it continues to enlarge a place for itself in the square or boll until the food supply has become exhausted or the vegetable tissues are so changed as to be unsuitable for food. By this time, as a rule, the interior of the square has been almost entirely consumed and the larval castings are spread thickly over the walls of the cavity. This layer becomes firmly compacted by the frequent turning of the larva as it nears the end of this stage. In the cell thus formed occur the marked changes from the legless grub to the fully formed and perfect beetle.

Throughout this stage the body of the larva preserves a ventrally curved, crescentic form. The color is white, modified somewhat by

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[1] Extract from Bulletin 51, Bureau of Entomology, p. 31.
[2] Extract from Bulletin 51, Bureau of Entomology, pp. 34, 35.

the dark color of the body contents, which show through the thinner, almost transparent portions of the body wall. The dorsum is strongly wrinkled or corrugated, while the venter is quite smooth. The ridges on the dorsum appear to be formed largely of fatty tissue. After becoming full grown the larva ceases to feed, the alimentary canal becomes emptied, and both the color and form of the larva are slightly changed. The dark color disappears from the interior and is replaced by a creamy tint from the transforming tissues within. The ventral area becomes flattened, and the general curve of the body is less marked. Swellings may be seen on the sides of the thoracic region, and when these are very noticeable pupation will soon take place.

THE PUPA.[1]

(Pl. III, *h*, *i*, *j*.)

When the pupal stage is first entered the insect is a very delicate object both in appearance and in reality. Its color is either pearly or creamy white. The sheaths for the adult appendages are fully formed at the beginning of the stage, and no subsequent changes are apparent except in color. The eyes first become black, then the proboscis, elytra, and femora become brownish and darker than the other parts. The pupa of the boll weevil can be distinguished readily from any other pupa which might be found in a cotton square or boll. Like all other curculionid pupæ, its beak rests on the venter of the body, with the legs drawn up at the sides and with the elytra on the dorsum as they will appear in the adult. But the boll-weevil pupa has two large quadrate tubercles on the prothorax, practically at the anterior apex of the body, and the abdominal segment which serves as the apex is produced in a rather chitinous flattened process, which is inflated at the middle and deeply quadrately emarginate at apex, leaving only two strong acute teeth projecting.

The final molt requires about 30 minutes. The skin splits open over the front of the head and slips down along the proboscis and back over the prothorax. The skin clings to the antennæ and the tip of the proboscis until after the dorsum has been uncovered and the legs kicked free. Then by violently pulling upon the skin with the forelegs the weevil frees first the tip of the snout and then the antennæ, and finally with the hind legs it kicks the shrunken and crumpled old skin off the tip of the abdomen.

THE ADULT.

(Pl. II, *a;* Pl. III, *d*, *f*, *g*.)

BEFORE EMERGENCE.

Immediately after its transformation from the pupa the adult is very light in color and comparatively soft and helpless. The proboscis is darkest in color, being of a yellowish brown; the pronotum, tibiæ, and tips of the elytra come next in depth of coloring. The elytra are pale yellowish, as are also the femora. The mouth parts, claws, and

[1] Modified and expanded from Bulletin 51, Bureau of Entomology, p. 38.

the teeth upon the inner side of the fore femora are nearly black. The body is soft, and the young adult is unable to travel, consequently this period is passed where pupation occurs. Usually two or more days are required to attain the normal coloring and the necessary degree of hardness to enable the adult to make its escape from the square or cell.[1] This is known as the teneral adult stage.

DESCRIPTION OF ADULT.

The following technical description of the species is taken from the Revision of Genera and Species of Anthonomini Inhabiting North America, by Dietz.[2]

Anthonomus grandis Boh.—Stout, subovate, rufo-piceous and clothed with coarse, pale-yellowish pubescence. Beak long, slender, shining, and sparsely pubescent at the base; striate from base to the middle, striæ rather coarsely punctured; apical half finely and remotely punctured. Antennæ slender, second joint of funicle longer than the third; joints 3–7 equal in length, but becoming gradually wider. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax one-half wider than long; base feebly bisinuate, posterior angles rectangular; sides almost straight from base to middle, strongly rounded in front; apex constricted and transversely impressed behind the anterior margin; surface moderately convex, densely and subconfluently punctured; punctures irregular in size, coarser about the sides; pubescence more dense along the median line and on the sides. Elytra oblong, scarcely wider at the base than the prothorax; sides subparallel for two-thirds their length, thence gradually narrowed to and separately rounded at the apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugulose, pubescence somewhat condensed in spots. Legs rather stout, femora clavate, anterior strongly bidentate, inner tooth long and strong, outer one acutely triangular and connected with the former at the base; middle and posterior thighs unidentate. Tibiæ moderately stout, anterior bisinuate internally, posterior straight; tarsi moderate, claws broad, blackish, and rather widely separate; tooth almost as long as claw. Long. 5–5.5 mm.; 0.20–0.22 inch.

SIZE OF WEEVILS.

The size of boll weevils is somewhat variable. It varies almost directly in proportion to the abundance of the larval food supply and the length of the period of larval development. It also depends upon the nature of the food, whether it is squares or bolls.[3] The smallest weevils are developed from squares which are very small, and which, for some reason, either of plant condition or of additional weevil injury, fall very soon after the egg is deposited. In such cases the supply of food is not only small, but possibly, owing to the immaturity of the pollen sacs, its quality is poor. Normally, squares continue to grow for a week or more after eggs are deposited in them, and such squares produce the weevils of average size and color.

The largest weevils are produced in bolls which grow to maturity. In them the food supply is most abundant, and the period of larval development is several times as long as it is in squares. Weevils reared from squares late in the season, where infestation has reached its maximum, are of small size, whereas weevils reared from large bolls are very noticeably larger. The extremes are so great that the largest and smallest weevils would be thought, by one not familiar

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[1] The foregoing is extracted from Bulletin 51, Bureau of Entomology, p. 39.
[2] Trans. Amer. Ent. Soc., vol. 18, p. 205.
[3] The following sentences are taken from Bulletin 51, Bureau of Entomology, p. 41.

with them, to be of entirely different species. So far as dimensions may convey an idea of the size, we may say that the weevils range from 2.5 mm. to 6.75 mm. ($\frac{1}{10}$ to $\frac{1}{4}$ inch) in length, measuring from base of beak to apex of elytra, and from 1 mm. to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ inch) in breadth at the middle of the body.

WEIGHT OF WEEVILS.

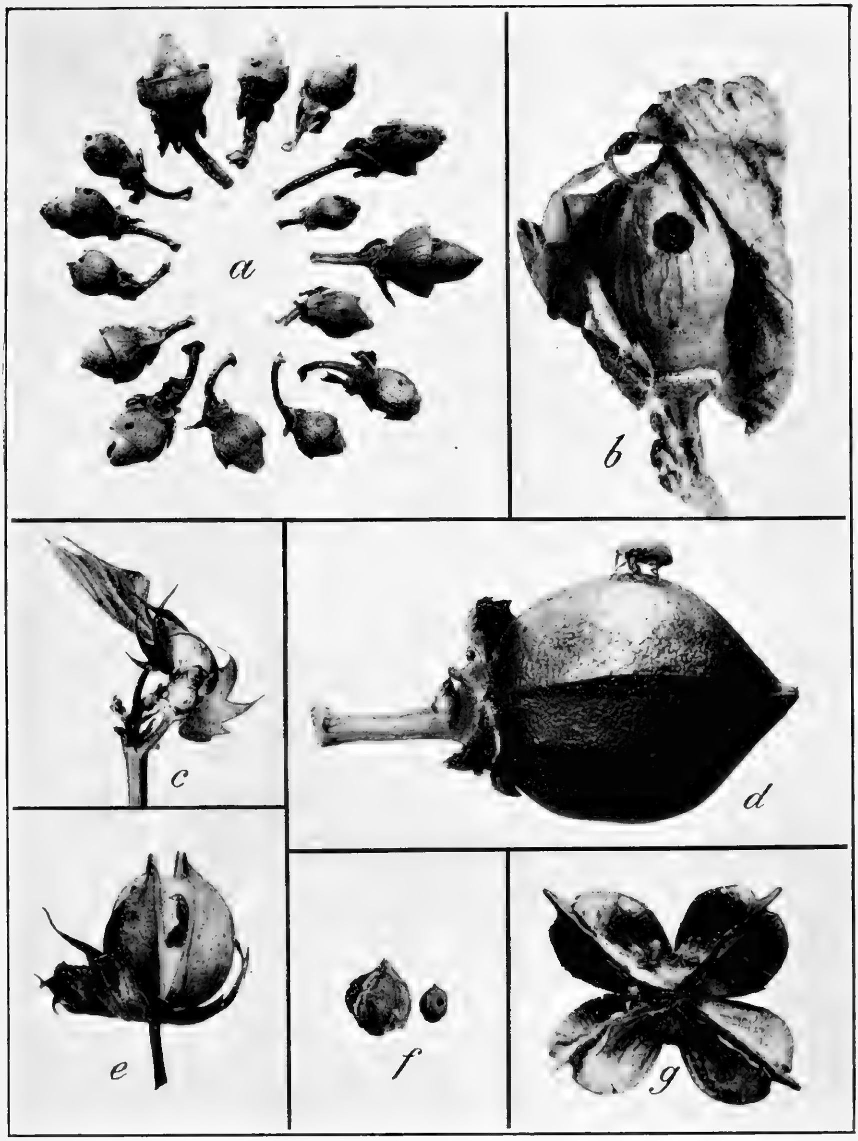
A number of interesting observations have been made at various times upon the weight of weevils in connection with the nature of the food supply. These observations have been tabulated, as follows:

TABLE VII.—*Weight of boll weevils from different sources.*

Source.	Condition when weighed.	Number.	Average weight.
			Grains.
Picked small squares	Fed	25	0.105
Average fallen squares	do	68	.231
Do	Unfed	36	.102
Do	Fed	9	.110
Fallen squares	do	15	.080
Large bolls	do	69	.268
Total		222	
Average			.192

COLOR OF WEEVIL.

Color is very often a variable character in insects, and the boll weevil presents considerable range in this respect. Normally, the general color becomes darker with age. Consequently, hibernated weevils are the darkest found, but another factor must be considered. As has been noted, whatever influences the size of the larva affects directly the size of the adult, and it is noticeable that weevils of the same size are also, as a rule, similar in color. In general, the smaller the size of the weevil, the darker brown is its color; the largest weevils are light yellowish brown. Between these two extremes are the majority of average-sized weevils, which are either of a gray-brown or dark yellow-brown color. In the opinion of Dr. W. E. Hinds the principal reason for the variation in color lies in the degree of development of the minute, hair-like scales, which are much more prominently developed in the large than in the small specimens, although the color of old specimens is often changed by the abrasion of the scales. These scales are yellow in color, while the ground color of the chitin bearing them is a dark brown or reddish brown. The development of the scales appears to take place mostly after the adult weevils have become quite dark in color, but before the chitin becomes fully hardened. They seem, therefore, to be, to a certain extent, an aftergrowth which depends upon the surplus food supply remaining after the development of the essential parts of the weevil structure.



THE ADULT BOLL WEEVIL AND EMERGENCE HOLES.

a, Squares of Peruvian cotton, showing emergence holes of the Peruvian cotton-square weevil; *b*, square of upland cotton, showing emergence hole of the cotton-boll weevil; *c*, adult boll weevil on cotton square; *d*, adult boll weevil puncturing cotton square; *e*, adult boll weevil emerging from cotton boll; *f*, small dry bolls, showing emergence holes; *g*, hull of boll, with weevils found hibernating. (Original.)

SECONDARY SEXUAL CHARACTERS.[1]

We are indebted to Dr. A. D. Hopkins, of the Bureau of Entomology for indicating the most strongly marked points of difference in the secondary sexual characters of the boll weevil. (See fig. 3.) The distinctive characters are found upon the snout and upon the last two abdominal segments. The differences are subject to some variation, but are still sufficiently constant to enable a close observer with the aid of a hand lens positively to differentiate males from females.

Female.—The snout of the female is slightly longer and more slender than that of the male. When viewed from above it usually appears to taper slightly from each end toward the middle. The antennæ are inserted slightly farther from the tip than is the case in the male. The insertion is at about two-fifths of the distance from the tip of the snout to the eyes. As a rule the surface of the snout is more smooth and shining than in the male. A slight depression,

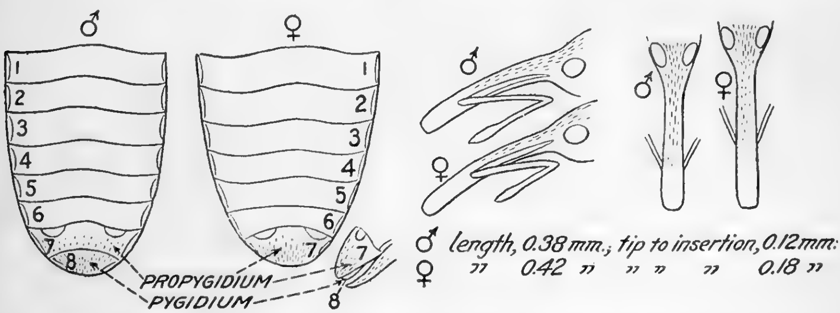


FIG. 3.—Secondary sexual characters of *Anthonomus grandis*. (From Hinds and Yothers, after Hopkins.)

rather elongated and much larger than any of the other punctures upon the snout, occurs between the bases of the antennæ. When the wing covers and wings are unfolded the abdomen shows seven distinct dorsal segments. The last segment visible in the female, called the propygidium, can be seen only from the sides.

Male.—In the male the snout is slightly shorter, thicker, and more coarsely punctured than in the female. The depression mentioned in the female is lacking. The antennæ are inserted at practically one-third of the distance from the tip of the snout to the eyes. The sides of the snout are very nearly parallel. In the abdomen the male shows eight distinct dorsal segments, the terminal segment (pygidium) not being covered by the propygidium as is the case in the female.

In general practice an examination of the beak is sufficient to determine the sex of each weevil.

[1] This discussion is modified from Bull. 77, Bureau of Entomology, pp. 91, 92.

SEASONAL HISTORY.

THE ADULT WEEVIL.

EMERGENCE.[1]

(Pl. IV, *b*, *e*; Pl. VI, *e*, *f*.)

The adult boll weevil's normal method of escape from squares and small bolls is by cutting with its mandibles a hole just the size of its body. In large bolls the escape of the weevil is greatly facilitated by the natural opening of the boll. Often the pupal cell is broken open by the spreading of the carpels, and when this is the case the pupa, if it has not already transformed, becomes exposed to the attack of enemies or, what is probably a more serious menace, to the danger of drying so as seriously to interfere with a successful transformation. If the cell remains unbroken the weevil always escapes by the path of least resistance, cutting its way through as in the case of a square.

CHANGES AFTER EMERGENCE.[2]

At the time of emergence the weevils are comparatively soft, and they do not attain their final degree of hardness for some time after they have begun to feed. The chitin is of an orange tinge at the time the weevils leave the squares or bolls, but after exposure for some time it turns to a dark chocolate brown.

PROTECTIVE HABITS.

Not only is the boll weevil protected from its enemies by its color, which resembles both the dry squares and also the pulverized soil upon which it frequently drops, but it has a protective habit, found more or less commonly among insects. At the first disturbance of the cotton plant, or sometimes even at a movement of a large object in the vicinity of the cotton plant, the boll weevil becomes very alert, raising its antennæ and standing almost motionless. If the disturbance continues, the weevil falls to the ground with its legs drawn up close to the body and the antennæ retracted against the beak, which is brought inward toward the legs. In this position it often remains motionless for some time, but if further disturbed, it will start up quickly, run a short distance and again fall over, feigning death. This habit is popularly known as "sulling" [3] or "playing possum." Frequently, in falling, the weevil comes in contact with some part of the plant and immediately relaxes and takes shelter on the plant, or sometimes it spreads its wings and flies away instead of falling to the ground. In July and August the weevils become more alert than at any other season of the year, and flight more frequently follows the dropping from the plants.

FOOD HABITS.

Before escaping from the square the adult empties its alimentary canal of the white material remaining therein after the transformation. The material removed in making an exit from the cell is not used as

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[1] Extracted from Bull. 51, Bureau of Entomology, pp. 39, 40.
[2] Extracted from Bull. 51, Bureau of Entomology, p. 40.
[3] Undoubtedly a corruption of "sulking."

food, but is cast aside. Weevils are ready to begin feeding very soon after they escape from the squares or bolls in which the previous stages have been passed. For several days thereafter both sexes feed almost continuously. They much prefer squares, but in confinement will feed upon leaves, flowers, or bolls. Under natural conditions any portions of the plants other than the squares and bolls are seldom attacked. The bolls are only slightly attacked so long as there is an abundance of uninfested squares.

[1] The method of feeding is alike in both sexes. The mouth parts are very flexibly attached at the tip of the snout (fig. 4) and are capable of a wide range of movement. The head fits smoothly into the prothorax like the ball into a socket joint and is capable of a considerable angle of rotation. The proboscis itself is used as a lever in prying, and helps to enlarge the puncture through the floral envelopes especially. Feeding is accomplished by a combination of movements. The sharply toothed mandibles serve to cut and tear, while the rotation of the head gives the cutting parts an auger-like action. The forelegs especially take a very firm hold upon the square and help to bring a strong pressure to bear upon the proboscis during certain portions of the excavating process. The outer layer of the square, the calyx of the flower, is naturally the toughest portion that the weevil has to penetrate, and only enough is here removed to admit the snout. After that is pierced the puncture proceeds quite rapidly, combinations of chiseling, boring, and prying movements being used. While the material removed from the cavity is used for food, the bulk of the feeding is upon the tender, closely compacted, and highly nutritious anthers or pollen sacs of the square. When these are reached the cavity is enlarged, and as much is eaten as the weevil can reach. The form of the entire puncture becomes finally like that of a miniature flask.

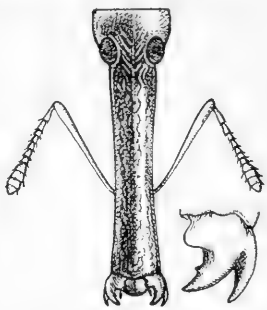

FIG. 4.—Cotton-boll weevil: Head, much enlarged, showing rostrum, with antennæ near middle and mandibles at end; mandible, more enlarged, at right. (Original.)

Only after weevils have fed considerably do sexual differences in feeding habits begin to appear; from this time on the females puncture mainly the base and the males the tip of the square.

Feeding punctures are much larger and deeper than are those made especially for the reception of the eggs; more material is removed from the inside of the square or boll and the opening to the cavity is never intentionally closed. Feeding punctures are most frequently made through the thinner portion of the corolla not covered by the calyx. The exposed tissue around the cavity quickly dries and turns brown from the starting of decay. As a number of these large cavities are often formed in one square (Pl. V, *c*), the injury becomes so great as to cause the square to flare immediately, often before the weevil has ceased to feed upon it. Squares so severely injured fall in a very short time. The injury caused by a single feeding puncture is often overcome by the square, which continues its normal course of development. When feeding punctures are made in squares which are nearly ready to bloom, the injury commonly produces a distorted

[1] The following four paragraphs are borrowed from Bulletin 51, Bureau of Entomology, pp. 50, 51.

bloom (Pl. V, *e*, *f*), and in very severe cases the boll will drop soon after setting.

After the females begin to oviposit their feeding habits become quite different from those of the males. Up to this time both sexes move but little, making a number of punctures in a single square; but from this point we must consider the feeding habits of the sexes separately.

Males puncture the tip portion of the square not covered by the calyx more often than do the females. The yellow or orange colored excrement is abundant, and owing to the somewhat sedentary habits of the males it accumulates often in rather large masses, so that it is often possible to tell whether a square in the field has been attacked by a male rather than by a female weevil. Observations made by Dr. Hinds on 70 specimens under both field and laboratory conditions show that for the first few days of their life the males make from six to nine punctures a day, but that during their entire life they average about 1.2 punctures per day and an average of 2.6 punctures per square, injuring only about two squares every three days. Whether in or out of doors, the activity of feeding decreases as the male becomes older.

After they begin to oviposit females seem generally to feed less upon one square or in one puncture than they do previous to that time. They obtain quite a considerable portion of their food from the excavations which they make for the deposition of their eggs, and as they show a strong inclination to oviposit only in clean or previously uninfested squares their wandering in search of such squares keeps their punctures scattered so long as plenty of clean squares can be found. When clean squares become scarce, the normal inclination can not be followed, and the number of punctures made in each square will be greatly increased.

Table VIII is presented to illustrate the feeding activity of both sexes:

TABLE VIII.—*Rate of making egg and feeding punctures by the boll weevil.*[1]

Character of lot.	Number of males.	Number of females.	Total.			Average.		
			Weevil days.	Feeding punctures.	Egg punctures.	Feeding punctures per weevil day.	Egg punctures per female day.	Period of observation.
								Days.
Hibernated weevils in laboratory	55	54	4,938	17,406	5,702	+3.5	+2.3	+45.3
Weevils of first generation in laboratory	31	27	3,258	16,487	3,565	+5.0	−2.4	−56.2
Hibernated females in field cage	....	4	93	284	489	+3.0	−5.3	−23.3
First-generation females in field cage	....	5	70	263	435	−3.8	+6.2	14.0
Males in laboratory	65	....	2,492	5,617	....	−2.3	....	+38.3
Males in field	5	....	145	177	....	1.2	....	+29.0
Total	156	90	10.996	40,234	10,191	....	....	....
Average	....	....	....	....	....	3.6	2.4	44.7

[1] Modified from Bulletin 51, Bureau of Entomology, p. 52.

EFFECTS OF BOLL-WEEVIL ATTACK ON LEAF AND SQUARES.

a, Cotton leaf much fed upon by adults; *b*, square with two egg punctures; *c*, flared square with many feeding punctures; *d*, square prevented from blooming by puncture; *e*, bloom injured by feeding punctures; *f*, poor blooms caused by feeding punctures. (Original.)

ABILITY TO LOCATE COTTON.

When hibernated weevils emerge from their winter quarters in search of food they are frequently long distances from the nearest cotton field. It has been a question of considerable interest whether the weevils are able to locate cotton or whether they find it by chance. Dr. A. W. Morrill conducted a series of experiments in the laboratory to test the attraction of cotton squares for the weevil, but the results were not conclusive. In the eight years of study of the boll weevil, there have been very few records of weevils on any other plants than cotton, notwithstanding the fact that special collections were made in the woods and fields near the cotton fields in search of boll weevils. In the season of 1905 extensive collections were made by means of sweeping nets by several men for weeks during the dispersion season, and yet not a single weevil was found outside of the cotton fields. All of this would indicate that there is some attraction of the weevils to cotton. The concentration of weevils upon the earliest plants in the spring and upon the greenest and most luxuriant portions of the fields in the fall are also evidences of the ability of the weevils to find desirable places for feeding.

FEEDING HABITS OF HIBERNATED WEEVILS.

Whether there be few or many hibernated weevils makes no difference in their feeding habits. The stage of the cotton at the date of emergence determines largely the nature of the food habits at that time. The first weevils to emerge obtain their food from the tender, rapidly growing, terminal portions of the young plants. They place themselves upon the node where the two cotyledons branch. In fact, this seems to be the point usually attacked in cases of very young cotton plants. In almost all cases the puncture of the weevil at this point results in the death of the plant. Sometimes the attack is made a little above the node on a petiole of the cotyledon, in which case the one cotyledon falls and the other remains, and the plant usually recovers. However, it frequently happens that the same weevil attacks both of the cotyledons. This form of attack is fatal to the seedlings unless they have become very vigorous—sometimes until they have developed two true leaves. Later the central bud, young leaves, or tender stems are attacked, and upon these the weevils easily subsist until the squares are developed. (See Pl. V, *a*.) In cases where the emergence from hibernation is very large the weevils may come out in such numbers upon the newly sprouted cotton as to stunt or even kill the growing plants by their depredations upon the terminal portion.

Weevils which have fed upon tender tips of plants seem perfectly satisfied with their food supply, and it appears that their first meal upon squares is largely the result of accident. After having begun to feed upon squares, however, it appears that their taste becomes so fixed that they normally seek for squares.

In the spring of 1895 Mr. E. A. Schwarz found the first emerged hibernated weevils working upon plants which had sprung from 2-year-old roots. In the spring of 1903 in one field of comparatively early cotton, 2 or 3 acres in extent, the senior author found, between April 24 and May 11, 23 weevils working on the buds and tender leaves of stubble plants before a single weevil was found on the

young planted cotton having from four to eight leaves. At Victoria, early in June, 1902, Mr. A. N. Caudell found, in examining 100 stubble plants growing in a planted field, that fully one-half of the squares upon these plants were then infested. The planted cotton was just beginning to form squares and was slightly injured at that time.

It appears, therefore, that stubble plants, where such exist, receive a large part of the first attack of the hibernated weevils, not because of any special attraction, but for the reason that they are present long before the planted cotton has come up. The occurrence of volunteer and stubble cotton in the fields in the early spring is of considerable importance in the boll-weevil problem. Throughout the coast regions, especially of southern Texas, stubble cotton is very common in the fields, and there is hardly a region of the South where volunteer cotton can not be found before the normal planting is up. (See Pl. VIII, *a*.)

It is by no means certain that all or even a large proportion of the hibernated weevils may be found upon the early plants, and this renders their use as traps entirely impracticable. A number of observations have shown that weevils frequently occur upon the planted cotton, even when numbers of vigorous stubble plants may be found within a comparatively short distance. In fact, at Victoria, Tex., in 1904, many weevils were found feeding upon the planted cotton for more than six weeks after the stubble plants were producing fruit.

DESTRUCTIVE POWER BY FEEDING.[1]

A glance at the figures in Table VIII is sufficient to show the great destructive power of the Mexican cotton-boll weevil. It may be seen that both in the field and in the laboratory the weevils of the first generation are more active in making punctures than are the hibernated weevils. These generations overlap too far to justify us in attributing this difference to the influence of a higher temperature alone, though this factor will account for a large part of it. A comparison of the figures for males alone with those for females alone or with those for males and females together shows that it is very conservative to state that males make less than half as many punctures as do females. By the habit of distributing their punctures among a greater number of squares the destructiveness of the females becomes at least five times as great as that of the males.

This great capacity for destruction has been one of the most evident points in the history of the spread of the weevil and has deeply impressed the entomologists who first studied the insect in Texas. In 1895 Mr. E. A. Schwarz, in writing of the work of the weevil at Beeville, said:

> Each individual specimen possesses an enormous destructive power and is able to destroy hundreds of squares, most of them by simply sticking its beak into them for feeding purposes.

ATTRACTIVENESS OF VARIOUS SUBSTANCES.

Experiments have proved that the report which has sometimes been circulated to the effect that cottonseed meal attracts the weevil is due to mistaking other insects for it. Many tests, both in the laboratory

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[1] Extracted from Bulletin 51, Bureau of Entomology, p. 61.

and in the field, have shown that sugar and molasses, either in solution or otherwise, have no attraction whatever for the weevil. Honey exerts a very weak attraction, but not enough to be of any practical use in control. In fact, it has not been found that any substance exerts a special attraction for the weevil. The experiments have dealt with many chemicals as well as plant decoctions.

SENSE OF COLOR.

A series of interesting observations on the color sense of the boll weevil was made by Mr. C. R. Jones at Calvert and Victoria, Tex., and Alexandria, La., in 1907. Tubes of different colors were placed in a box, all with an equal amount of sunlight, and the weevils were given food. The observations were made at intervals during the day, and each time the weevils were all shaken back into the box. Table IX shows the total number of weevils found at each color for the series of observations and also the weighted average attractiveness. Fourteen shades were used, but these may be grouped under eight colors. The three most attractive shades were light-blue, dark-green, and light-pink. While it is rather difficult to explain the results, it nevertheless appears that there is some preference for certain colors on the part of the weevil.

TABLE IX.—*Relative attractiveness of colors to the boll weevil.*

Color.	Number of observations.	Number of weevils attracted.	Average attractiveness.
			Per cent.
Blue	64	461	7.2
Green	43	261	6.0
Yellow	32	123	3.8
Red	107	411	3.8
White	11	24	2.1
Purple	32	29	.8
Orange	10	5	.5
Black	21	6	.2

MOVEMENTS ON FOOD PLANT.

Various observations have been made to determine the amount of movement of weevils at night. In July, 1904, at a mean temperature of 76.3° F., Mr. A. C. Morgan found, in an aggregate of 134 weevil nights, that eight weevils had moved but 25 times. Each weevil had moved only once every six nights. On cloudy days weevils are much more sluggish than on sunny days. Relative humidity influences the activity, but no definite observations on this point have been made.

The effect of temperature on locomotive activity may well be illustrated by a series of laboratory experiments conducted by Dr. A. W. Morrill. A thermometer was passed through a cork and inclosed in a test tube, which in turn was placed within a hydrometer cylinder of sufficient depth to inclose it. Weevils were inclosed in the test tube with the thermometer, and the temperature of the cylinder was varied either by heating gently or by the use of ice water. Starting with the thermometer at 64° F., the 10 weevils inclosed were found to move slowly, half of them being quiet. As the temperature was gradually

raised the activity of the weevils increased up to 105° F. When the temperature reached 95° F. or over the weevils were running up and down the tube. By filling the cylinder with cold water the temperature was lowered to 86° F., at which point the weevils began to cluster at the top on the cork and were crawling slowly. By the addition of ice in the cylinder the temperature was lowered to 59° F., at which point five weevils were struggling on the bottom of the test tube or clinging to one another, four were clustered on the stopper, while one was slowly crawling downward. At 50° F. six weevils at the bottom showed slight signs of life, and one was crawling slowly. At 45.5° F. slight signs of life were still shown, while at 40° F. occasional movements only were noted. When the temperature was raised weevils began crawling as 50° F. was passed, and at 64° all had left the bottom and were crawling upward. Some recovered more quickly than did others. The temperature was again lowered, this time by the use of salt with ice. All movement ceased at 37° F. The cooling, however, was continued to 33° F., after which it was slowly raised to 42° F., at which point movements began.

EFFECTS UPON SQUARES AND BOLLS OF FEEDING BY THE BOLL WEEVIL.

From numerous large, open feeding punctures a square becomes so severely injured that it flares very quickly, often within 24 hours. (See Pl. V, *c*.) Males usually make the largest punctures, which they always leave open while they remain for a day or more working upon the same square. It has been often found that squares thus injured by a male will flare before the weevil leaves it. The time of flaring depends upon the degree of injury and the size of the square. Thus small squares which receive only a single large feeding puncture in the evening are found widely flared in the morning. On the other hand, large squares which are within a few days of the time of their blooming may receive a number of punctures without showing any noticeable flaring. Frequently a square which has flared widely will be found later to have closed again and to have formed a distorted bloom, and occasionally such squares develop into normal bolls. (See Pl. V, *e*, *f*.) In squares of medium size a single feeding puncture does not usually destroy the square. The destruction of a square by feeding results either from drying or decay which follows the weevil injury.

TABLE X.—*Destruction of squares by the feeding of the boll weevil.*

Period.	Total number of squares punctured.	Number of squares with feeding punctures.	Total number of feeding punctures.	Average number of feeding punctures per square.	Average number of days before falling.
June-July	751	170	335	1.9	5.8
August-September	426	183	383	2.0	4.4
October-November	176	74	216	2.9	15.2
Total	1,353	427	934		
Weighted averages				2.0	7.0

INJURY BY BOLL WEEVIL TO SQUARES.

a, Bloom checked by attacks of larva; *b*, square opened, showing grown larva; *c*, square opened, showing pupa; *d*, dwarfed boll opened, showing one larva and two pupae; *e*, weevil escaping from square; *f*, emergence hole of adult in square. (Original.)

INJURY BY BOLL WEEVIL TO BOLLS.

a, Three larvæ in boll; *b*, emergence hole in dry unopened boll; *c*, two larvæ in boll; *d*, weevils puncturing boll, *e*, opened boll, with two locks injured by weevil; *f*, large bolls severely punctured. (Original.)

Table X shows that the number of feeding punctures per square is determined by seasonal influences, as is also the average number of days before falling. A comparison of the average time from the date of the attack to the falling of the square shows that squares which are only fed on, fall, as a rule, somewhat more quickly than do squares which only contain larvæ and have never been fed upon. Flaring takes place more rapidly as the result of feeding injury by the adult than from oviposition and injury from the developing stage. While only one egg is generally laid in a square, it appears from Table X that two feeding punctures are usually made in a square.

Bolls are quite largely fed upon after infestation has reached its height. Small and tender bolls are often thoroughly riddled by the numerous punctures and fall within a short time. (See Pl. VII.) Larger bolls may receive many more punctures but do not fall. In bolls an abnormal woody growth sometimes takes the place of the punctured fiber, and a softening and decay of the seeds often accompanies this change. One or more locks may be destroyed, while the remainder of the boll develops in perfect condition.

SUSCEPTIBILITY OF VARIOUS COTTONS.[1]

During 1903 and 1904 experiments were conducted at Victoria, Tex., to ascertain the relative susceptibility of several varieties of American Upland, Sea Island, Egyptian, and Cuban cottons. The observations at the laboratory were made by carefully examining the plants, looking into each square, and removing every weevil and infested square found. If there were any distasteful or resistant cotton among these it would surely be found in this way, and if any variety were especially attractive to the weevils it would be equally apparent. Since infested squares were removed, the accident of association or proximity would not determine the location of the weevils found, but all might be considered as having come to the cotton with equal opportunities to make their choice of food, and accordingly their location has been considered as indicating such choice. The period of observation extended from June to November, except with the Cuban cotton, which was planted late and began to square during the latter part of August. For the purpose of this comparison both the several varieties and the various plats of the American cotton will be considered together, as no evidence of preference was found among them.

In making a comparison of the results three elements must be considered for each variety of cotton: First, the number of plants of each variety; second, the number of days during which each kind was under observation; third, the total number of weevils found on each class of cotton. The elements of numbers of plants and time under observation may be expressed by the product of those two factors forming a term which we may call "plant days." The total number of weevils found upon any class of cotton divided by the number of plant days will give the average number of weevils attracted by each plant for each day, and these numbers furnish a means of direct comparison and show at a glance the average relative attractiveness of

[1] The following discussion is extracted, but modified, from Bul. 51, Bureau of Entomology, pp. 61-64.

each class of cotton. The results of this series of experiments are tabulated below:

TABLE XI.—*Relative attractiveness of various cottons to the boll weevil.*

Class of cotton.	Number of plants.	Total.			Average.		Relative attractiveness.
		Plant days.	Weevils found.	Infested squares.	Weevils per plant per day.	Infested squares per weevil.	
1903.							
American	62	4,920	287	3,507	0.058+	12.2+	1.0
Cuban	5	120	11	136	.092−	12.4−	1.6+
Sea island	8	552	64	1,089	.116−	17.0+	2.0
Egyptian	8	808	207	2,013	.256+	9.7+	4.4+
Total of 3 non-American cottons	21	1,480	282	3,238	.191−	11.5−	3.3−
1904.							
American	60	3,780	346	....	.0914	....	1.0
Sea island	5	315	117	....	.371+	....	4.0
Egyptian	4	252	102	....	.405−	....	4.4+

An examination of Table XI shows that American Upland cotton is less subject to attack by the weevil than any of the others, and that Egyptian (*Mit Afifi*) is by far the most susceptible. The weevils gathered so thickly on the Egyptian cotton that the plants could not produce sufficient squares to keep ahead of the injury, and therefore the average number of squares for each weevil is only three-fourths as great with that variety as with the less-infested kinds, but the average injury to each square was greater than with any other. It is possible that the greater amount of nectar secreted by the Egyptian cotton plants is responsible for this increased attraction of the weevils.

The results are still further sustained by observations upon larger areas of American and Egyptian cotton under field conditions in three localities in Texas, no weevils being removed from either kind. At Victoria, Tex., on August 26, 1903, an examination showed that 96 per cent of Egyptian squares were infested, while an average of 13 fields of American showed 75.5 per cent. At Calvert, Tex., on September 4, Egyptian showed 100 per cent infested, while the American varieties growing alongside showed 91 per cent. Similar results were found at San Antonio. Though growing in close proximity, the Egyptian produced no staple whatever, while the American gave better than an average yield in spite of the depredations of the weevil.

At Victoria, in the experimental tract during 1904, three varieties of Egyptian cotton (Mit Afifi, Janovitch, and Ashmouni) were tested side by side with American varieties. The Egyptian varieties uniformly failed to make a pound of cotton, while the American varieties averaged 400 pounds per acre.

In accordance with these observations, it appears that in developing a variety of cotton which shall be less susceptible to weevil attack, by far the most promising field for work lies among the American varieties, and of these the very early maturing kinds are most promising.

The question of choice of different varieties for food was tested in the laboratory by Dr. A. W. Morrill, by placing squares of two kinds of cotton, American and Egyptian, in alternate rows in a rearing cage

so lettered and numbered that each square could be exactly located. Weevils were then placed so that they could take their choice of these squares, and observations from 8 a. m. to 6 p. m. were made upon the location and activity of the weevils. Though this experiment was repeated four times no positive evidence was obtained to show that weevils had any choice as to which kind of squares they fed upon. Table XII presents a summary of these results.

TABLE XII.—*Rearing-cage observations upon boll weevil choice of American and Egyptian squares.*

Experiment.	Period of observation.	Number of observations.	Weevils used.	American squares.				Egyptian squares.			
				Total number.	Attacked.	Feeding punctures.	Egg punctures.	Total number.	Attacked.	Feeding punctures.	Egg punctures.
1	12 m. to 8 a. m.	8	10	16	12	15	5	16	5	12	3
2	11.45 a. m. to 9.45 a. m.	5	10	16	5	19	1	16	5	13	3
3	12 m. to 5 p. m. day after	5	10	16	7	25	2	16	9	27	2
4	11.45 a. m. to 9 a. m.	5	10	16	6	17	6	16	8	14	3
5	6 p. m. to 8 a. m.	1	18	4	2	7	0	4	2	10	0
	Total	24	58	68	32	83	14	68	29	76	11

In experiments 1 and 2 the American squares were attacked more extensively than were the Egyptian, while in experiments 3 and 5 greater injury was done to the Egyptian. In experiment 4 the smaller number of egg and feeding punctures made in the Egyptian squares is counterbalanced by the larger number of squares attacked. Although the totals from these five tests show slightly less injury to the Egyptian than to the American squares, it could hardly be expected that two arbitrarily chosen series, even if of the same variety, would show any closer agreement in the points of comparison made in this table than is therein shown by the American and Egyptian squares.

Field examinations made in Cuba and Mexico on the native varieties of cotton showed them to be as susceptible to serious weevil injury as are the cultivated cottons. In some localities in Central America the dwarf character of the cotton grown, the very open method of cultivation, and certain protective adaptations on the part of the plants result in the production of fair crops, though the varieties of cotton grown are by no means immune to weevil attack.

DURATION OF LIFE OF ADULT WEEVILS.

The subject of longevity is one which naturally divides itself into several headings. Many factors must be considered, among which are the nature of the food supply, seasonal conditions, the sex of the individual, and the time of entrance into and emergence from hibernation.

The maximum record of longevity of any boll weevil is that of a hibernated weevil at Tallulah, La. (1910), which was fed squares after emergence and lived a total of over 335 days. The maximum recorded period of hibernation without food is 240 days, and the maximum recorded length of life of hibernated weevils provided with food

after emergence is 130 days for males at Dallas, Tex. (1907), and 118 days for females at Calvert, Tex. (1907). The maximum recorded length of life of hibernated weevils unfed after emergence is 90 days for males and 88 days for females, both records being made at Dallas in 1907.

A considerable number of records are available to illustrate the relative sustaining power of the various kinds of weevil food. (See Table XIII.) These records are especially valuable in making comparisons with the sustaining power of other plants suspected of being possible food plants. It will be noticed that the same food has varying sustaining power at different seasons.

TABLE XIII.

DURATION OF LIFE OF REARED BOLL WEEVILS WITHOUT NORMAL FOOD.

Season.	Sustenance provided.	Number of weevils.	Number of weevil days.	Average longevity.	Maximum longevity.
June-July	Hay	18	47.7	2.5	7
Do	Oats	15	44.9	2.9	7
Do	Corn	10	34	3.4	5
Total for reared weevils with grain.		43	126.6	2.9	7
July	Tie vine	5	15	3	3
May	Hibiscus leaf	2	6	3	3
July	Sunflower	5	16	3.2	4
May	Okra leaf	3	10	3.3	4
July	Pigweed	5	17	3.4	4
Do	Bloodweed	5	18	3.6	5
Do	Bermuda grass	5	19	3.8	5
Total for reared weevils on weed leaves.		30	101	3.3	5
June-July	Water	79	339.8	4.3	9
August-October	do	72	306.3	4.2	11
Total for reared weevils on water only.		151	646.5	4.28	11
June	Jap. Hibiscus buds	12	25	2.0	3
August	do	9	19	2.1	4
July	Callirrhoe buds	42	235	5.6	11
June	*Hibiscus africanus* buds	16	92	5.7	14
July	Hollyhock buds	3	18	6.0	+7
Do	*Hibiscus moscheutos* buds	6	36	6.0	8
June	Okra buds	10	78	7.8	10
September	*Hibiscus militaris* buds	42	305	7.2	10
September-November	do	18	486	27.0	[1]+43
Total for reared weevils on malvaceous buds.		158	1,294	8.1	43
September	Fresh sorghum cane	17	193	11.3	20
October-November—hibernation quarters offered.		26	626	24.0	45

DURATION OF LIFE (AFTER EMERGENCE) OF HIBERNATED WEEVILS WITHOUT NORMAL FOOD.

Season.	Sustenance provided.	Number of weevils.	Number of weevil days.	Average longevity.	Maximum longevity.
June-July	Excelsior	13	32.5	2.5	4
Do	Rice	14	45.2	3.2	4
Total for hibernated weevils without water.		27	77.7	2.8	4
March-May	Water	5,701	59,021.8	10.3	90

[1] This weevil then entered hibernation and remained therein 126 days.

On sweetened water 12 weevils lived an average of a little less than 6 days. Six weevils fed upon molasses alone lived an average of 11.5 days.

Without food or water 50 weevils, just developed but not fed, lived an average of 5 days; 15 which were 7 weeks old lived 6 days; and 18 which were one month old lived 7.5 days.

TABLE XIV.—*Duration of life of boll weevils with normal food.*

Season.	Sustenance provided.	Number of weevils.	Number of weevil days.	Average longevity.	Maximum longevity.
July-September	Bolls	37	684.5	18.5	+20
September-November	do	45	981.0	21.8	69
Total for weevils fed on bolls		82	1,665.5	20.3	69
February-July	Foliage	4,261	103,931.1	24.3	130
October-December	do	92	2,950.9	32.0	
Total for weevils fed on foliage		4,353	106,882.0	24.5	130
April-June	Squares	170	12,439.4	73.1	105
June-July	do	91	3,363.2	36.9	58
August-September	do	64	4,796.0	74.9	135
September-October	do	18	1,170.0	65.0	+76
October-December	do	10	359.0	35.9	
Total for weevils fed on squares		353	22,127.6	62.7	135

These records show the following longevity for weevils fed on different portions of the cotton plant: On bolls, 20.3 days; on foliage, 24.5 days; on squares, 62.7 days. The sustaining power of foliage is therefore about 20 per cent higher than that of bolls, and that of squares 150 per cent higher than that of foliage. This indicates that the squares are by far the most suitable form of food.

A number of observations were made on the relative longevity of weevils of different generations when fed upon cotton squares. Weevils of the first generation lived 57 days; of the third, 48.5 days, and of the fifth, 65 days.

Newly reared weevils evidently have not the vitality of weevils emerged from a long hibernation, for they can not live so long on water alone. The boll weevil can find nourishment in several species of malvaceous plants which will sustain life twice as long as water alone, and in certain conditions as long as cotton foliage. It is interesting to note that the sweetened water from sorghum cane had almost three times the sustaining power of pure water.

In connection with these studies figures were obtained upon the relative food value of the various foods to the two sexes. The data obtained may be tabulated as follows.

TABLE XV.—*Duration of life of boll weevils according to sex.*

Condition.	Season.	Food provided.	Males.			Females.		
			Number.	Weevil days.	Longevity.	Number.	Weevil days.	Longevity.
Hibernated	June	None	7	13.3	1.9	6	19.2	3.2
Reared	June-July	Hay	9	19.8	2.2	9	27.9	3.1
Do	do	Oats	7	18.9	2.7	8	26.0	3.25
Do	do	Corn	5	17.0	3.4	5	17.4	3.4
Hibernated	June	Rice	8	27.2	3.4	6	18.0	3.0
Reared	do	Water	4	14.8	3.7	8	30.8	3.85
Hibernated	March-June	do	2,638	27,052.5	10.2	1,980	19,895.5	10.0
Reared	July-September	Bolls	16	315.2	19.7	21	319.2	15.2
Hibernated	March-July	Foliage	1,672	42,185.7	24.6	1,337	34,752.1	25.9
Do	do	Squares	90	7,207.0	80.0	68	4,752.0	69.8
Reared	July-October	do	57	3,198.0	56.1	44	2,432.0	55.2
Total			4,513	80,069.4	17.7	3,492	64,290.1	18.4

Table XV in some respects bears out other findings as to the superior hardihood of the female sex. It will be noticed that the female's superior vitality is shown in all the cases where the food supply is abnormal. Nevertheless, it is noticeable that in the case of weevils fed on squares and bolls the males had the greater longevity.

CANNIBALISM.[1]

It is hardly proper to speak of cannibalism as a food habit of the boll weevil, but the facts observed may well be recorded here. Under the impulse of extreme hunger weevils have several times showed a slight cannibalistic tendency.

Seven beetles were confined in a pill box without food. On the third day six only were alive. Of the seventh only the hardest chitinized parts (head, proboscis, pronotum, legs, and elytra) remained, the softer parts having been eaten by the survivors.

In another box containing 12 adults the leaf supplied for food was insufficient, and on the fourth day eight were dead, four were partly eaten, and others had lost one or more legs each.

In another case a few young adults and a number of squares containing pupæ were placed in a box together with a few fresh squares to serve as food for the adults. When the box was opened after a number of days one adult was found having its elytra eaten through and most of its abdomen devoured. In spite of this mutilation the victim was still alive and kicking slowly. The squares were still fresh and fit for food, so that this is really the clearest case of cannibalism observed.

Frequently more than one larva hatches in a square, and when this is the case a struggle between them is almost certain to take place before they become full grown. Many cases have been observed in which squares contained one living and one or more smaller dead larvæ, while in a few cases the actual death struggle was observed.

[1] From Bulletin 51, Bureau of Entomology, p. 48.

SEASONAL PROPORTION OF SEXES.

The most careful records of the sexes have been made in connection with the hibernation period. The records are presented herewith in tabular form, grouping the specimens as hibernated weevils, reared weevils taken during the spring and summer, and autumn weevils which were about to hibernate:

TABLE XVI.—*Sex of hibernated boll weevils.*

Year.	Locality.	Male.		Female.	
		Number.	Per cent.	Number.	Per cent.
1902–03	Victoria, Tex.	269	60.8	174	39.2
1903–04	Calvert, Tex.	40	59.7	27	40.3
1903–04	Victoria, Tex.	203	57.1	153	42.9
1905–06	Dallas, Tex.	173	57.7	127	42.3
1905–06	Victoria, Tex.	84	59.6	57	40.4
1906–07	Dallas, Tex.	1,668	54.1	1,412	45.9
1906–07	Calvert, Tex.	948	52.9	846	47.1
1906–07	Victoria, Tex.	1,660	61.3	1,049	38.7
Total		5,045		3,845	
Weighted averages			56.8		43.2

TABLE XVII.—*Sex of spring and summer reared boll weevils.*

Year.	Locality.	Male.		Female.	
		Number.	Per cent.	Number.	Per cent.
1902	Victoria, Tex.	240	48.0	260	52.0
1903	do.	140	53.1	124	46.9
1906	Dallas, Tex.	63	44.7	78	55.3
1907	Overton, Tex.	9	47.4	10	52.[illegible]
1910	Tallulah, La.	475	54.7	393	45.3
Total		927		865	
Weighted average			51.7		48.3

TABLE XVIII.—*Sex of autumn boll weevils ready to enter hibernation.*

Year.	Male.		Female.	
	Number.	Per cent.	Number.	Per cent.
1904	557	63.7	317	36.3
1904	31	62.0	19	38.0
1905	63	57.7	127	42.3
1906	173	68.9	78	31.1
1906	173	57.7	127	42.3
1906	19	57.6	14	42.4
1906	29	52.7	26	47.3
Total	1,045		708	
Weighted average		60.0		40.0
Total and weighted average for all seasons	7,017	57.2	5,418	42.8

From these determinations it appears that males are somewhat more numerous than females, the percentage based on our observations being 57.2 males to 42.8 females. It is noticeable also that the males are in preponderance throughout the year. Since the males are less active in their movements than are the females, the advantage of the existence of the majority of males becomes apparent. The larger number of males and the more active habits of the females serve to increase the chances for the meeting of the sexes.

It has been shown by rearing experiments conducted at low temperatures that the retardation of the development, such as is due to cold weather, favors the development of the males.

FERTILIZATION.

AGE AT BEGINNING OF COPULATION.

After the adult weevils have left the squares a certain period of feeding is necessary before they arrive at full sexual maturity. This period varies in length according to the temperature prevailing and appears to bear about the same ratio to the developmental period as does the pupal stage. With weevils fed upon leaves alone the period preceding copulation is about twice the normal length, in the cases observed, of those having squares to feed upon. Mr. Cushman, in observations at Tallulah, La., in 1910, found that the period from emergence of the female to copulation varied from two to seven days, with an average of 4.4 days. During hot weather it is probable that this period averages three or four days, but as the weather becomes colder it increases gradually until the weevils may become adult, feed for a time, and go into hibernation without having mated. It should not be understood, however, that weevils do not usually copulate before hibernation. Mr. C. E. Hood made numerous observations of the exercise of this function in the fall of 1909 at Mansura, La.

SEXUAL ATTRACTION AND DURATION OF COPULATION.

The distance through which the attraction of the female insect will influence the male varies extremely. In observations made by Dr. Hinds at Victoria, Tex., it was found that the male was unable to recognize the female at a much greater distance than an inch. Observations carried on in the field, as well as in the laboratory, tend to show that the sexes are attracted only when they meet, as they are likely to do either on the stems or upon the squares of the plant.

In a considerable number of cases that were timed the average duration of the sexual act was very nearly 30 minutes. The earliest spring records of copulation available are for April 15.

DURATION OF FERTILITY.

A number of females which were known to have mated were isolated to determine the duration of fertility. Although the limit was not determined exactly, the results proved very striking. Several of the females laid over 225 eggs each, and nearly all of them proved fertile. Selecting three cases in which the facts are positively known, it appears that fertility lasted for an average of something over 66 days

and that during this period these females deposited an average of nearly 200 eggs. The maximum limits may possibly be considerably higher. In fact, a single union seems to insure the fertility of as many eggs as the average female will lay, and its potency certainly lasts for a period fully equal to the average duration of life. It is probable, however, that there are many cases of repeated fertilization of females.

PARTHENOGENESIS.

Several series of experiments were conducted at Dallas, Tex., in August, 1906, to determine whether the boll weevil can reproduce parthenogenetically. Mr. R. A. Cushman kept 24 unfertilized females in confinement for 259 weevil days, and found that they deposited only 43 eggs, all being placed outside of the squares. No fertile eggs were laid. The rate of oviposition was one egg per female every six days. With a similar purpose Dr. Hinds isolated 40 individuals as soon as they matured.[1] Each beetle was supplied daily with fresh, clean squares and careful watch was kept for eggs. The first point noticed was that no eggs were found till the weevils were about twice as old as females usually are when they deposit their first eggs. After they began to oviposit it was found that a very small proportion of the eggs were deposited in the usual manner within sealed cavities in the squares, but nearly all of them had been left on the surface, usually near the opening of an empty egg puncture. This same habit was shown by a number of females, and so can not be ascribed to the possible physical weakness of the individuals tested. The number of eggs deposited was unusually small, and the few placed in sealed cavities failed to hatch. After somewhat more than a month had been passed in isolation a few pairs were mated to see if any change in the manner of oviposition would result. The very next eggs deposited by these fertilized females were placed in the squares and the cavities sealed up in the usual manner, showing that the infertile condition had been the cause of the abnormal manner of oviposition.

OVIPOSITION.

AGE AT BEGINNING OF OVIPOSITION.

As has been shown, normal oviposition never takes place until after fertilization has been accomplished, but it usually begins soon afterwards. Observations upon the age at which the first eggs are deposited can be made more easily and more positively than those upon the age at which fertilization takes place. In a general way, therefore, the observations here given may be cited as also throwing light upon the time of beginning copulation. Table XIX is introduced to summarize the various observations which have been made upon the period preceding oviposition. It will be noticed that the range is from 4 to 14 days during the breeding season. Of course, the weevils which hibernate before ovipositing are not to be considered as of this category.

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[1] Bulletin 51, Bureau of Entomology, pp. 91, 92.

TABLE XIX.—*Age of the boll weevil at beginning of oviposition.*

Date adult.	Place.	Date first egg.	Number of females.	Number weevil days.	Average age.
June 8–14, 1903	Victoria, Tex	June 16–19	27	150.0	5.55
July 8–11, 1910	Tallulah, La	July 14–19	11	66.0	6.00
July 29–31, 1910	do	Aug. 5–7	7	44.0	6.29
Aug. 14–22, 1910	do	Aug. 21–28	16	106.0	6.66
Sept. 4–9, 1902	Victoria, Tex	Sept. 16–17	8	72.5	9.06
Sept. 10–20, 1910	Tallulah, La	Sept. 18–Oct. 8	9	116.0	12.89
Oct. 2, 1902	Victoria, Tex	Oct. 16	4	56.0	14.00
Nov. 9–11, 1902	do	Nov. 16–19	10	73.0	7.30
June 8–Nov. 11		June 16–Nov. 19	92	683.5	7.40

EXAMINATION OF SQUARES BEFORE OVIPOSITION.

In the course of a great many observatious upon oviposition it was found that females almost invariably examine a square carefully before they begin a puncture for egg deposition. This examination is conducted entirely by means of senses located in the antennæ and not at all by sight. In fact, the sense of sight appears to be of comparatively small use to this weevil. In regard to the actual time spent in the work of examination before beginning a puncture, over sixty observations are recorded. These show that the average time is over two minutes. This examination of squares is made by females only when they intend to oviposit. Males have never been observed acting in this way, nor do females generally do so when their only object is to feed.

SELECTION OF UNINFESTED SQUARES FOR OVIPOSITION.

The sense by which the weevil examines the squares frequently enables it to detect an infested condition when no external sign is visible. Females sometimes refrain from placing eggs in squares, even when they are apparently searching for a place to oviposit and anxious to do so. The acuteness and accuracy of the preliminary examination is well shown by the fact that when provided with more squares than they have eggs to deposit they do not often place more than one egg in a square. Where a totally infested condition is reached, as is frequently the case in the field, no choice between infested and uninfested squares could be exercised, and then, unless the female happens to be in a condition to refrain from oviposition, she is forced to deposit more than one egg in a square. Table XX illustrates the distribution of egg and feeding puncture as collated from many records.

TABLE XX.—*Selection of squares and relation of feeding to oviposition of the boll weevil.*

Place and time of observation.	Total squares attacked.	Squares with 1 egg each.		Squares with more than 1 egg each.		Squares with both egg and feeding punctures.		Squares fed on only.	
		Number.	Per cent of total squares.	Number.	Per cent of total squares.	Number.	Per cent of total squares.	Number.	Per cent of total squares.
In laboratory, 1902	630	477	75.7	19	3.0	24	3.8	110	17.4
In field, 1902	151	56	37.0	33	21.8	46	30.4	16	10.5
In field, 1903	560	317	55.9	83	14.8	50	8.9	110	19.6
In field, 1905	1,036	531	51.2	415	40.0	90	8.6	0	0.0
In field, 1907	2,679	413	15.4	0	0.0	1,832	68.4	434	16.2
Total	5,056	1,794		550		2,042		670	
Average percentage			35.4		10.8		40.3		13.2

The observations show that 86.7 per cent of all squares attacked received eggs. It may also be seen that 40.9 per cent of all squares oviposited in received only one egg each. The squares which were only fed upon formed but 13.2 per cent of the total number attacked, and, as has been shown above, those receiving both egg and feeding punctures constituted 40.3 per cent. As the weevil injury overtakes the production of squares the proportion of squares containing both egg and feeding punctures increases rapidly. Where several eggs are placed in a square it is rarely the case that more than one larva develops.[1] If two or more hatch in a square one is likely to destroy the others when their feeding brings them together. Should eggs be placed in squares which already contain a partly grown larva, those hatching would probably find the quality of the food so poor that they would soon die without having made much growth. Since one egg will insure the destruction of the square and a number of eggs would do no more, it is plain that the possible number of offspring of a single female is increased directly in proportion to the number of her eggs that she places one in a square. Favorable food conditions for the larva are likewise best maintained by the avoidance of feeding upon squares in which eggs have been deposited and also by refraining from ovipositing in squares which have been much fed upon. Selection of uninfested squares is, therefore, of the greatest importance in the reproduction of the weevil, since this insures the most favorable conditions for the maturity of the largest possible number of offspring.

Feeding and oviposition are common in the same boll, but unless the infestation is very heavy it appears that only rarely is more than one egg placed in one lock, though several are often deposited in the same boll. The number deposited depends considerably upon the size of the boll. The smallest, which have just set, receive but one, as do the squares, and these fall and produce the adult weevil at about the same period as in the case of squares. Bolls which are larger when they become infested have often been found to be thickly punctured and to contain 6 or 8, and in one case 15, larvæ. (See Pl. VI, *d;* Pl. VII, *c*.)

DEPENDENCE OF REPRODUCTION UPON FOOD OBTAINED FROM SQUARES.[2]

During the fall of 1902 a series of experiments, lasting for 12 weeks, was made to determine the length of life of weevils fed solely upon leaves. In one lot, consisting of nine males and eight females, the average length of life of the females was 25 days, while that of the males was 36 days. Though this period far exceeded the normal time usually passed between the emergence of adults and the beginning of egg deposition, no eggs were found. Dissection of the females which lived longest showed that their ovaries were still in latent condition, though the weevils were then 81 days old. Few instances of copulation were observed among weevils fed upon leaves alone, and among nearly 70 weevils which were thus tested no eggs were ever deposited. After a period of three weeks upon leaves, 11 weevils were transferred to squares. Females in this lot began to lay in four days, and four of them deposited 323 eggs in an average time

[1] In one case four normal pupæ were found in a single square. This observation was made at Shreveport, La., by Mr. H. Pinkus.

[2] From Bull. 51, Bureau of Entomology, pp. 112, 113.

of 20 days. The conclusion seems plain that so long as leaves alone are fed upon, eggs do not develop, while a diet of squares leads to the development of eggs in about four days. It is worthy of note that the interval between the first feeding upon squares and the deposition of the first eggs is almost the same with these weevils taken in middle life as with weevils which have just emerged.

An examination of hibernated females taken in the spring of 1903, which had fed for six weeks upon cotton leaves, showed that their ovaries were still latent. Copulation was rarely observed among hibernated weevils until after squares had been given them. In a few days after feeding upon squares, mating and oviposition began. The average period was from three to five days, and, having once begun, oviposition continued regularly.

It has been found that food passes the alimentary canal in less than 24 hours. Assimilation therefore must be very rapid. It is evident that while leaves will sustain life certain nutritive elements found only in squares are essential in the production of eggs.

These experiments were repeated in 1904 with similar results.

Upon dissecting weevils just taken from hibernation, it was found that females contained no developed eggs, but that their ovaries were in an inactive condition, similar to those of females which had fed for months entirely upon leaves during the previous fall. Upon examining females taken from stubble cotton later in the spring, but before squares had appeared, it was found that they also were in similar condition. This was also true of females kept in the laboratory from the time of emergence from hibernation until squares became abundant, with only leaves for food. It seems peculiar that upon a purely leaf diet eggs are not developed, but all observations made indicate that this is the case. It can not be said definitely whether the females examined had been fertilized, but it is certain that they were not ready to deposit eggs.

PLACE OF EGG DEPOSITION.

The location of egg punctures, while variable, still shows some selection on the part of the weevil. This may be due partly to the form of the squares and partly also to the size of the weevil, but whatever the explanation, the fact remains that in a majority of cases the egg puncture is made on a line about halfway between the base and the tip of the square. When so placed the egg rests either just inside the base of a petal or among the lowest anthers in the square, according to the varying thickness of the floral coverings at that point. Punctures are very rarely made below this line, though they are sometimes made nearer the tip. Almost invariably the egg puncture is started through the calyx in preference to the more tender portion of the square, where the corolla only would need to be punctured. With bolls no selection of any particular location has been found, but eggs seem to be placed in almost any portion.

THE ACT OF OVIPOSITION.

While engaged in making egg punctures, the favorite position of the weevil is with its body parallel to the long axis of the square and its head toward the base. The tip of the weevil's body is thus brought near the apex of a medium-sized square. It may be that the position

described is especially favorable for obtaining a firm and even hold and this may have something to do with the regularity with which it is assumed. Having selected her location, the female takes a firm hold upon the sides of the square and completes her puncture while in this position.

The female begins drilling a hole by removing with the mandibles a little flake of the outer epidermis. Then, with her feet strongly braced by gnawing and pushing with an auger-like motion, she thrusts her beak into the tender portion of the square. At the bottom of the puncture she makes a small cavity by gnawing, at the same time moving about the hole with the beak as a pivot. Withdrawing her beak, she turns about with the center of her body as a pivot. This places the tip of her abdomen directly over the puncture, into which she thrusts her ovipositor. The ovipositor is protruded to the bottom of the cavity in which it appears to be firmly held in position by the two terminal papillæ and the enlarged terminal portion. Slight contractions of the abdomen occur while this insertion is being made. In a few moments much stronger contractions may be seen, and often a firmer hold is taken with the hind legs as the egg is passed from the body, and its movement may be seen as it is forced along within the ovipositor and down into the puncture. Only a few seconds are required to complete the deposition after the egg enters the opening to the cavity. Having placed the egg, the ovipositor is withdrawn, and just as the tip of it leaves the cavity a quantity of mucilaginous material, usually mixed with some solid excrement, is forced into the opening and smeared around by means of the tip of the abdomen. This seals the egg puncture, and the act of oviposition becomes complete. Sometimes the weevil fails to locate the puncture immediately with her ovipositor. In this event she searches excitedly, moving the tip of the abdomen about feeling carefully over the surface of the square. In this search, however, she never moves her front feet, apparently using the position of these as a guide to the distance through which she should search. Failing to locate the puncture in this way she again turns around and searches for it with her beak and antennæ. When the cavity has been found again the female invariably enlarges it before turning again to insert the ovipositor. If the search with the antennæ does not prove successful, the female generally makes another puncture in the same manner as at first.

The usual habit of the female in puncturing through the calyx enables it to seal the wound more thoroughly because of the healing power possessed by the calyx tissue. Punctures made in the corolla must remain open or are closed only by the slight filling of mucilaginous excrement by the weevil. Punctures through the calyx will, in most cases, be healed by the natural outgrowth of the tissue so as completely to fill the wounds in a manner analogous to the healing of wounds in the bark of a tree. The custom of the weevil in sealing up its egg punctures with a mixture of mucous substance and excrement is of great advantage and assistance to the plant in the healing process. While undoubtedly applied primarily as a protection to the egg, it serves to keep the punctured tissues from drying and decay, and thus promotes the process of repair. As a result of the growth thus stimulated in the calyx, the wound is healed perfectly in a short

time, and a corky outgrowth appears above the general surface plane. This prominence has been termed a "wart." The healing is completed even before the hatching of the egg takes place, and thus both egg and larva partake of the benefit of its production. Occasionally warts develop from feeding punctures which were small, but the exact conditions under which this takes place have not been determined. Nevertheless, the presence of warts is the most certain external indication of oviposition in squares. In a series of observations they were found to follow oviposition in 84 per cent of the cases.

TIME REQUIRED TO DEPOSIT AN EGG.

Careful observations have been made upon the time of egg deposition. As in all other processes of the life history of this insect, the period of egg deposition is influenced by climatic conditions. It was found at Tallulah, La., in the early part of the summer of 1910, that the time required for making the puncture varied from 1 minute and 20 seconds to 8 minutes and 27 seconds, with an average of 3 minutes and 36 seconds. On the other hand, at Victoria, Tex., in October, the average time was 5¼ minutes, and the range from 1 to 13 minutes. At Tallulah the period for the deposition of the egg and the sealing of the puncture varied from 2 minutes and 45 seconds to 9 minutes and 30 seconds, with an average of 4 minutes and 41 seconds. At Victoria the period ranged from 3 to 16 minutes and averaged 7½ minutes.

STIMULATING EFFECT OF ABUNDANCE OF SQUARES UPON EGG DEPOSITION.[1]

Four actively laying females were confined together upon a few squares from September 22 to October 14, 1902. During this period they laid a total of 227 eggs, or an average of 2.37 eggs per weevil per day. For the next 13 days these same weevils were isolated and supplied with an abundance of squares. During this shorter period they laid 236 eggs, or 4.54 eggs per female daily.

These figures are the more striking, because the stimulation was plainly shown in spite of the general tendency to lay fewer eggs as the weevils grow older and as the average temperature becomes lower.

ACTIVITY OF WEEVILS IN DIFFERENT PARTS OF THE DAY.

Two series of observations have been carried on to determine the hourly activity of the weevils. The experiments at Victoria were conducted in the early part of September, when the temperature was ranging from a little under 70° F. to 95° F. during the day. It was found that there was almost a perfect coincidence between the temperature curve and the curve of the average activity of the females in ovipositing. This is shown in the accompanying diagram (fig. 5).

It also appeared that the activity of the weevils began and ceased at about 75° F. Perhaps this indicates that the act of oviposition requires a zero of effective temperature different from that of development. This would be entirely analogous to conditions in flowers, where it is found that the various functions of the plant are governed

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[1] Modified from Bulletin 51, Bureau of Entomology, pp. 87, 88.

by independent laws of effective temperature. It appears also that the activity is much less on cloudy days than on clear days. At Tallulah, La., in 1910, observations were made on the periodic division of daily oviposition. The results are shown in Table XXI.

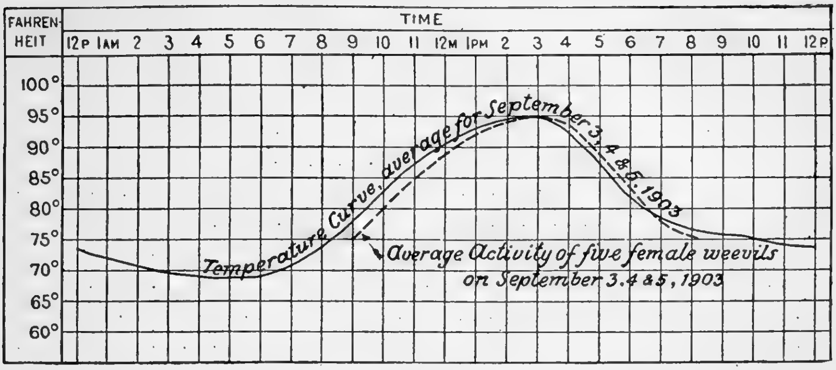

FIG. 5.—Diagram showing average activity of five female boll weevils. (After Hunter and Hinds.)

TABLE XXI.—*Summary of periodic division of oviposition, based upon nine boll weevils, Tallulah, La., July, 1910.*[1]

Period.	Total eggs laid.	Average number of eggs per hour.	Per cent of total oviposition in each period.	Average eggs per weevil per hour.
5 p. m.–7.30 p. m	25	5.00	23.15	0.63
7.30 p. m.–4 a. m	10	.59	9.26	.07
4 a. m.–9 a. m	21	2.10	19.44	.26
9 a. m.–1 p. m	17	2.13	15.74	.27
1 p. m.–5 p. m	35	4.38	32.41	.55

From these records it may be seen that the warmest part of the day is the most active period for the weevils.

SEASONAL RATE OF OVIPOSITION.

Since the period of reproductive activity of the boll weevil is so long, the rate at which eggs are deposited is a question requiring much time for its determination. The rate of oviposition is at least as strongly influenced by variations in temperature as is the rate of development, and it is very probable that some of the previously unaccountable and abrupt variations in the rate upon succeeding days may be explained by the relative humidity or by the amount of sunshine. The rate is influenced also by the abundance of clean squares which the weevil can find, so that it is greater in the early part of the season as the degree of infestation is approaching its limit than after infestation has reached its maximum. Several series of observations have been made upon the rate of egg deposition. These have been tabulated below in Table XXII.

[1] From Cushman, Journ. Econ. Ent., vol. 4, p. 436.

TABLE XXII.—*Seasonal rate of oviposition of the boll weevil.*

Place.	Time.	Number of females.	Number of weevil days.	Average period of oviposition.	Total number of eggs.	Average number of eggs daily.	Average total number per female.	Maximum number in one day.
Victoria, Tex.	Aug.-Dec., 1902	[3] 1	135	135	255	1.88	255.0	....
Do.	Sept.-Oct., 1902	40	247	6	1,248	5.05	31.2	....
Do.	....do....	4	23 13	9	227 236	2.37 4.54	116.0	....
Do.	Oct.-Dec., 1902	9	352	39	990	2.81	110.0	....
Do.[1]	May-July, 1903	[3] 51	2,018	39	5,254	2.60	103.0	18
Do.[2]	June-Sept., 1903	[3] 24	1,395	58	3,541	2.53	147.5	....
Do.	Aug., 1904	3	21	7	112	5.32	37.3	....
Terrell, Tex.	Sept., 1904	4	12	3	55	4.56	13.7	....
Dallas, Tex.	July-Aug., 1905	2	23	11	81	3.68	40.5	8
Do.	Aug.-Sept., 1905	3	108	36	233	2.15	77.6	20
Tallulah, La.[1]	June-Aug., 1910	[3] 9	310	34	1,830	5.90	203.3	20
Do.[2]	Aug.-Oct., 1910	[3] 4	183	45	887	4.85	221.7	12
Total		154	4,840	....	14,949	....	....	20
Average		....	....	31	....	3.13	97.07	....

[1] Hibernated weevils.
[2] First generation weevils.
[3] Observed for entire oviposition period and used in discussion of fecundity.

The influence of temperature upon the rate of oviposition may be shown by the following diagram (fig. 6), which expresses in a single line the mean number of eggs laid daily at a given temperature. There is, of course, more or less fluctuation from the mean, and it is due mostly to differences in humidity.

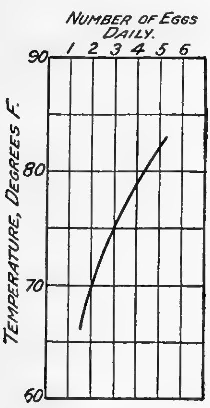

FIG. 6.—Diagram to illustrate influence of temperature on average rate of oviposition of boll weevil. (Original.)

The maximum number of eggs deposited by any weevil in one day has been recorded by Mr. Cushman as 20 at Tallulah, La. At Victoria, Tex., Dr. Morrill recorded two weevils to have laid 108 eggs in three days, or at the rate of 18 eggs per day. Dr. Morrill found that the size of weevils did not affect the rate per day, as four very small females laid 761 eggs at the rate of 3.3 eggs per day. It will be noticed that this rate is higher than the average of all the records in Table XXII. The number of eggs produced on the first day of oviposition varies from one to seven. About 67 per cent of the weevils at Victoria were found to oviposit fewer than three eggs on the first day.

IS THE FECUNDITY OF THE WEEVIL DECREASING?

In view of the fact that recent observations have shown a decrease in the fecundity of the gipsy moth in Massachusetts,[1] we have selected from the foregoing table (Table XXII) on the seasonal rate of oviposition the rather meager data bearing on the question of whether the fecundity of the boll weevil is decreasing. We find 76

[1] Howard and Fiske, Bull. 91, Bur. Ent., U. S. Dept. Agr., pp. 109, 110, 1911.

weevils at Victoria, Tex., in 1902 and 1903, laying an average of 119 eggs in an average period of 46 days, and at the rate of 2.6 eggs per day, with a maximum of 18 eggs in one day; while at Tallulah, La., in 1910, 13 weevils laid an average of 209 eggs in an average period of 37 days and at the rate of 5.7 eggs per day, with a maximum of 20 eggs in one day. While these facts appear to indicate that the fecundity of the weevil is not decreasing, they do not, on the other hand, because of the great difference in the places of observations, prove an increase. More detailed data will be obtained on this point in the future.

PERIOD OF OVIPOSITION.

With the exception of hibernated weevils it appears that oviposition begins with the majority of females in about seven days after they emerge as adults to feed and continues uninterruptedly until shortly before death. In the case of 43 weevils observed at Tallulah, La., in 1910, the average preoviposition period was 7.72 days, the minimum 5, and the maximum 23 days. While females frequently deposit their last eggs during the last day of their life, a period of a few days usually intervenes between the cessation of oviposition and death.

The known maximum number of eggs laid by a single individual is 304. This was in the case of a weevil which lived for 275 days and deposited eggs at the rate of 7.6 eggs per day for 41 days. The maximum period of oviposition recorded is 135 days. In the case of 52 hibernated weevils at Victoria the period of oviposition averaged about 48 days, the maximum being fully 92 days. In an average rate with 21 females in the first generation the actual period was almost 75 days, the maximum being 113 days. The average period for the females of the first two generations appears to be longer than that for any other. In the third generation the average period for 11 females was 58 days, the maximum being 99 days, and in the fifth generation for 5 females the period averaged 48 days, with the maximum only 62 days. At Tallulah, La., in 1910, the average oviposition period was found to be 34.44 days. The average period for all of the records available is but 31 days.

The approach of cold weather cuts short the activity of the weevils which become adult after the middle of August, thereby decreasing the length of their oviposition period. Weevils which pass through the winter usually live longest, but as it requires more or less vitality to pass through the long hibernation period, their activity in the spring is thereby lessened.

EFFECTS OF OVIPOSITION UPON SQUARES.

As has been explained elsewhere, the attack of the weevil on the square causes it to form an absciss layer, which ultimately causes it to separate entirely from the plant. One of the immediate effects of attack is the flaring of the square, that is, the spreading of the bracts and their subsequent yellowing and drying. (See Pl. I.) Flaring may result from many other causes besides boll-weevil injury. When resulting from weevil injury it does not begin, as a rule, immediately after the injury, but only within from one to three days of the time

when the square will be ready to fall. In especially severe cases of feeding injury flaring often results in less than 24 hours. Occasionally the growth of the square overcomes the injury from feeding, and the bracts, after having flared, again close up and the square continues its normal development and forms a perfect boll. When injured by the feeding of a young larva as the direct result of successful oviposition, flaring was found in 193 cases to take place in an average of 7 days from the deposition of the egg. (See Pls. V, VI.)

After an average period of 2.5 days subsequent to flaring the square was found to fall to the ground, although it may sometimes hang by a thread of the bark. The average time from egg deposition to the falling of the square in 539 cases from June to September was found to be about 9.6 days, which is about the middle point of the weevil development. It has been shown in another place (Table XXVII) that the period before the falling of the square has a direct bearing upon the period of the development of the weevil.

PROBABLE ORIGINAL BREEDING HABIT.

There is nothing to indicate that the boll weevil has changed its food plant, although it may have done so. It is now confined, as far as we know, to the various species and varieties of the genus Gossypium. The boll weevil belongs to a genus of weevils every species of which is confined in its food habits to a single species or genus of food plants. The majority of the species of Anthonomus and perhaps all that belong to the true genus normally breed in buds. It is therefore reasonable to assume that the normal habit of the boll weevil is to breed in the cotton buds or "squares," and that its habit of breeding in the bolls is an adaptation due to the necessity of providing for the great number of weevils which develop in the later part of the season. A study of the length of the development of many species of Anthonomus leads the authors to believe that the short developmental period in squares is perfectly normal and that the longer period in bolls is due merely to environmental conditions, as is explained under the subject of development.

THE EGG.

DURATION OF EGG STAGE.

Concealed as the eggs are beneath several layers of vegetable tissue, it is impossible to examine them to ascertain the exact length of the egg stage without in some degree interfering with the naturalness of their surroundings. The beginning of the stage is easily obtained by confining female weevils with uninfested squares. By making a large series of observations about the time that the larvæ should hatch it is possible to obtain the average length of the egg stage. The extreme range which has been observed in the duration of this stage is from 1 to 17 days, while the average period for the whole number of observations is but 3.7 days. It is possible that the embryo can undergo an even greater retardation without losing its vitality. The period of embryonic development is lengthened by decreases in the temperature and also by lowered atmospheric humidity. Thus it was found that between 79° F. and 81° F. the

egg stage averaged 1.9 days at Alexandria, La., 2.61 days at Tallulah, La., 3.73 days at Victoria, Tex., and 4.1 days at Dallas, these differences corresponding quite regularly to the differences in the humidity of the various places. Table XXIII is presented to show the data

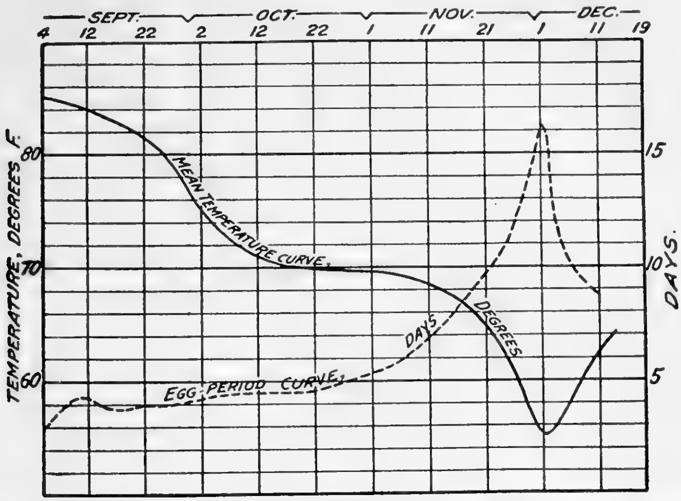

FIG. 7.—Diagram illustrating relationship of temperature to the egg period of the boll weevil at Victoria, Tex., in 1902. (Original.)

which have been obtained on this stage, and is accompanied by two diagrams (figs. 7 and 8) to illustrate the relationship between mean temperature and the length of the egg period.

TABLE XXIII.—*Duration of the egg stage of the boll weevil.*

Place.	Year.	Eggs laid.	Eggs hatched.	Number of eggs laid.	Total number of egg days.	Average period.	Mean temperature.
						Days.	° *F.*
Victoria, Tex.	1902	Sept. 4–29	Sept. 7–Oct. 3	384	1,434	3.73	81.0
Do	1902	Oct. 7–20	Oct. 11–24	95	430	4.52	73.0
Do	1902	Nov. 7	Nov. 13	12	72	6.0	
Do	1902	Nov. 24–28	Dec. 5–15	17	214	12.59	62.0
Do	1902	Dec. 2–9	Dec. 15–18	19	264	13.9	
Do	1903	May 27–June 5	May 30–June 9	25	93	3.75	72.5
Alexandria, La.	1907	Aug. 31–Sept. 5	Sept. 2–7	229	436	1.9	79.2
Dallas, Tex.	1908	July 17–20	July 20–23	35	145	4.1	81.6
Do	1908	Aug. 14	Aug. 17	11	33	3.0	88.0
Tallulah, La.	1910	June 27–July 10	July 1–12	44	115	2.61	78.9
Total				871	3,236		
Average						3.7	74.6

HATCHING.

While still within the egg the larva can be seen to work its mandibles vigorously, and although a larva has never been seen in the act of making the rupture which allows it to escape from the egg, it is believed that the rupture is first started by the mandibles. The larvæ do not seem to eat the membranes from which they have escaped, but owing to the extreme delicacy of the skin it is almost impossible to find any trace of it after the larva has left it and begun feeding on the square, the membranes having been found in only a few cases.

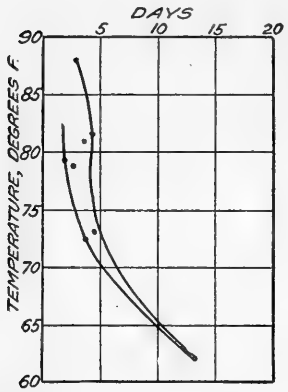

FIG. 8.—Diagram illustrating relationship of temperature to the egg period of the boll weevil and showing variations due to humidity. (Original.)

HATCHING OF EGGS LAID OUTSIDE OF COTTON FRUIT.

It occasionally happens that a female is unable to force an egg into the puncture prepared to receive it, and the egg is laid on the outside of the square or boll. Eggs so placed usually shrivel and dry up within a short time. To test the possibility of a larva making its way into the square from the outside a number were protected from drying. Of the 19 eggs tested, 6 hatched in from two to three days. In no case, however, was the young larva able to make its way into the square, and it soon perished. The hatching of eggs laid outside, therefore, appears to be of no importance, since the larvæ must perish without doing any damage.

On August 23, 1906, Mr. R. A. Cushman observed the hatching of two larvæ under water from eggs which had been submerged over 24 hours.

EATING OF EGGS DEPOSITED OUTSIDE.

The number of eggs left outside increases as the female becomes weakened and is especially noticeable shortly before her death. Repeated observations have shown that unfertilized females generally deposit their eggs on the outside, and only occasionally is an infertile egg deposited normally, though the attempt is regularly made to do so. The number of such eggs which may be found is greatly decreased by a peculiar habit observed many times, which will be described. Occasionally it appeared that the puncture which the female had made for the reception of an egg was too narrow to receive it, and after a prolonged attempt to force it down the female would withdraw her ovipositor, leaving the egg at the surface. She would then turn immediately and devour the egg. In some cases more than one has been devoured after repeated failures to place them properly in the squares.

PERCENTAGE OF EGGS THAT HATCH.

Definite records have not been kept regarding the percentage of eggs that hatch, but in the many hundreds of eggs followed during these observations very few have failed to hatch. Though some are much slower in embryonic development than are others laid at the same time and by the same female, it is probable that less than 1 per cent of the eggs are infertile or fail to hatch. It must be considered, however, that proliferation crushes many eggs. This proliferation is most aggressive against the eggs in the bolls in the late fall.

THE LARVA.

FOOD HABITS.[1]

It is plainly the instinct of the mother weevil to deposit her egg so that the larva upon hatching will find itself surrounded by an abundance of favorable food. In the great majority of cases this food consists principally of immature pollen. This is the first food of the larva which develops in a square, and it must be both soft and nutritious. Often a larva will eat its way entirely around the inside of a square in its pursuit of this food. In most cases the larva is about half grown before it feeds to any extent upon the other portions of the square. It may then take the pistil and the central portion of the ovary, scooping out a smoothly rounded cavity for the accommodation of its rapidly increasing bulk. So rapidly does the larva feed and grow that in rather less than a week it has devoured two or three times the bulk of its own body when fully grown. It sometimes happens that the square is large when the egg is deposited therein, and the bloom begins to open before the injury done by the larva becomes sufficient to arrest its development. In many cases of this kind the larva works its way up into the corolla and falls with it when it is shed, leaving the young boll quite untouched. Occasionally the flower opens and fertilization is accomplished before any injury is done the pistil, and in rare cases a perfect boll results from an infested square. Sometimes the larva when small works its way down into the ovary before the bloom falls, and in such cases the small boll falls as would a square. (See Pl. VI, *a*, *b*, *d*.)

In large bolls the larvæ feed principally upon the seed and to some extent upon the immature fiber. A larva will usually destroy only one lock in a boll, though two are sometimes injured. When the infestation is severe a number of weevils, occasionally as many as six or even more, may be developed in a single boll, which is completely destroyed by the feeding of the larvæ. (See Pl. VII, *a*, *c*.)

GROWTH.

The rate of growth, of course, is dependent upon many external conditions. It has been found that in squares during the hot weather, the length of the body increases quite regularly by about 1 mm. a day. Full grown larvæ vary in length from 5 to 10 mm. across the tips of the curve. Larvæ of normal size in squares average from 6 to 7 mm. The largest larvæ are developed in bolls which grow to maturity.

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[1] From Bulletin 51, Bureau of Entomology, p. 49.

MOLTS.

To accommodate the rapid growth of the larvæ two or three molts occur. The first occurs at about the second day, and the second at about the fourth day. Whether a third molt occurs before pupation can not be positively stated, but having occasionally found larvæ which had certainly just molted, but which were not larger than the usual size of the second molt, we are led to suspect that three larval molts may sometimes occur, though possibly not always. In bolls where the length of the larval stage is often three or four times as great as that usually passed in squares, it seems almost certain that more than two larval molts occur regularly.

According to Dr. Hinds's observations the skin splits along the back, starting at the neck, and is then pushed downward and backward along the venter of the larva. The cast head shield remains attached to the rest of the skin.

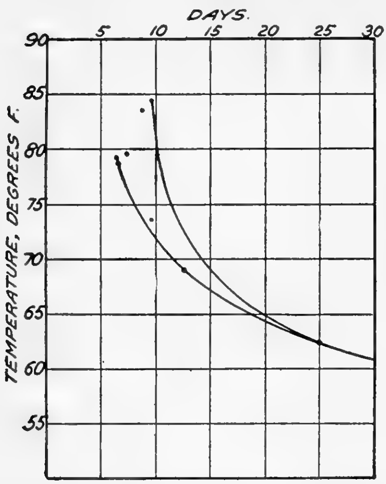

FIG. 9.—Diagram illustrating relationship of temperature to larval period of the boll weevil and showing range due to humidity. (Original.)

DURATION OF LARVAL STAGE.

The length of the larval stage, as a rule, is about equal to the sum of that of the egg and pupal stages. It lengthens as the temperature falls and also as the amount of moisture decreases. It is also probably influenced by the nature and condition of the food supply. These influences will be discussed more fully under the subject of developmental period, as more data are available for the entire period than for any of the stages in this period.

The observations which have been made upon the duration of the larval stage are tabulated and charted below (Table XXIV and fig. 9).

TABLE XXIV.—*Duration of the larval stage of the boll weevil.*

Place.	Year.	Hatched.	Pupated.	Number of larvæ.	Total number of larva days.	Average larval period.	Mean temperature.
						Days.	°*F.*
Victoria, Tex	1902	Sept. 6	Oct. 5	195	1,462.5	7.5	78.7
Do	1902	Sept. 26	Oct. 21	15	142.5	9.5	73.6
Do	1902	Nov. 11	Dec. 12	15	375.0	25.0	62.5
Victoria, Tex. (ice box)	1904	Aug. 26–Sept. 3		88	1,100.0	12.5	69.0
Alexandria, La	1907	Aug. 26–Sept. 5	Aug. 28–Sept. 7	149	1,096.0	7.3	79.9
Dallas, Tex	1908	July 18–29	Aug. 1–12	50	435.5	8.7	83.7
Do	1908	Aug. 3–19	Aug. 17–31	44	390.0	8.8	84.1
Tallulah, La	1910	June 27–July 7	July 7–17	98	618.5	[1] 6.3	79.1
Total		June 27–Nov. 11	July 7–Dec. 12	654	5,620.0	8.5	76.2

[1] The extremes were 5.2 and 7.3 days.

PUPAL CELLS.

As the larva becomes larger it gradually forms about itself a hardened black cell, composed of its cast skins and excrement. This cell is of a very tough leathery nature and seems to hold its moisture for a considerable period. In bolls the cell is even harder, as it becomes more or less mixed with lint and attains a considerable firmness, which often gives the cell the hardness and appearance of a seed. These pupal cells frequently include a portion of the hull of a seed, and it has also been found that the larva sometimes forms its cell within a single cotton seed. In these cells the larva transforms to the pupal stage. (See Pl. IX.)

PUPATION.

The formation of the adult appendages has progressed considerably before the last larval skin is cast. The wing pads appear to be nearly one-half their ultimate size. The formation of the legs is also distinctly marked, and the old head shield appears to be pushed down upon the ventral side of the thorax by the gradual elongation of the developing proboscis. Finally, the tension becomes so great that the tightly stretched skin is ruptured over the vertex of the head, and it is then gradually cast off, revealing the delicate white pupa. The cast skin frequently remains for some time attached to the tip of the abdomen. The actual period of ecdysis is about 45 minutes.

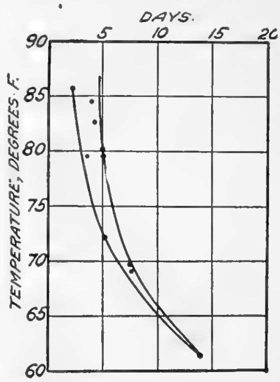

Fig. 10.—Diagram illustrating relationship between temperature and the pupal period of the boll weevil and showing variations due to humidity. (Original.)

THE PUPA.

ACTIVITY.

The pupal stage of the boll weevil is more or less an active stage. The pupa is so constructed, with a forked prong at the posterior tip and with two strong tubercles on the thorax, as to have an axis upon which it can revolve without injuring its more delicate appendages. As the cell is almost round, this movement of the pupa is more or less free in all directions and tends to make the cell harder and more durable. A person with acute hearing can detect the presence of a pupa by holding a square close to the ear. (See Pl. VI, *c, d.*)

DURATION OF THE PUPAL STAGE.

In general, it may be said that the length of the pupal stage is about equal to that of the larval stage minus the length of the egg stage. This stage varies considerably, as do the two previous stages, the range being from 2 days at high temperature to 14 or more days at low temperature. During the winter it may be as long as several months. Table XXV and figure 10 are presented to illustrate the variations in the pupal period in their relationship to mean temperature. It may be stated briefly that the length of the pupal stage increases as the temperature decreases, and that the average humidity also influences the stage in the same manner.

TABLE XXV.—*Duration of the pupal stage of the boll weevil.*

Place.	Year.	Pupated.	Emerged.	Number of pupæ	Total number of pupa days.	Average pupal period.	Mean temperature.
							Degrees F.
Victoria, Tex	1902	July 6–13	July 10–16	27	97	3.5	82.65
Do	do	July 12–18	July 16–22	22	84	3.8	
Do	do	July 18–23	July 23–28	86	392	4.5	
Do	do	July 24–25	July 29–30	23	111	4.8	
Do	do	Sept. 15	Sept. 20	4	20	5	79.05
Do	do	Oct. 21–24	Oct. 27–28	5	24	4.8	....
Do	do	Nov. 2–6	Nov. 9–13	29	212	7.3	69.2
Do	do	Dec. 2–13	Dec. 15–29	4	56	14	61.55
Victoria, Tex., ice box	do			88	660	7.5	69
Dallas, Tex	1907	June 13	June 19	1	5	5	80.1
Alexandria, La	do	Aug. 5	Aug. 7–8	20	43	2.1	85.7
Do	do	Sept. 10–13	Sept. 16–18	141	717	5	72.1
Dallas, Tex	1908	Aug. 1–6	Aug. 5–11	10	41	4.1	84.5
Tallulah, La	1910	July 7–17	July 14–21	50	167.5	[1] 3.3	79.1
Total	1902–1910.	June 13–Dec. 13	June 19–Dec. 29.	510	2,629.5	5.1	74.3

[1] The extremes were 2.8 and 3.9 days.

PERCENTAGE OF WEEVILS DEVELOPED FROM INFESTED SQUARES.[1]

During the season of 1902 part of the many squares gathered in infested fields for the rearing of weevils were followed to learn something of the percentage which produced normal adults. No examination was made for those not yielding a weevil. The decay of the square during the period from its falling to the maximum time that must be allowed for weevils to escape normally so obliterates any small amount of work by a larva that it is difficult, even with examination, to determine accurately the number of dead small larvæ.

TABLE XXVI.—*Percentage of boll weevils from infested squares.*

Locality.	Approximate date.	Number of squares.	Number of weevils.	Percentage of squares producing weevils.
	1902.			
Victoria, Tex	July to August	1,125	360	32.0
Guadalupe, Tex	August	387	108	28.0
	1903.			
Victoria, Tex	June	334	106	32.0
Do	June to August	873	355	41.0
Do	August to September	368	192	52.0
	1904.			
Do	June to September	951	469	49.3
Total		4,038	1,590	39.4

It seems safe to conclude that throughout the season fully one-third of the squares which fall after receiving weevil injury may be expected to produce weevils.

[1] From Bul. 51, Bureau of Entomology, p. 92.

LIFE CYCLE.

DURATION OF LIFE CYCLE.

We have shown that the average duration of the egg stage under different conditions is 3.7 days, of the larva 8.5 days, of the pupa 5.1 days, of the preoviposition period 7.7 days, and of the oviposition period 31 days. Consequently, the average time from the deposition of the egg to the completion of oviposition by the resulting adult is 56 days. The average required for the combined egg, larval, and pupal stages is 17.3 days. The larva requires about 2½ times as many days as the egg, and the pupa about two-thirds of the time required for the development of the larva.

SEXUAL VARIATIONS.

There are several factors which govern the duration of the life cycle of the weevil. The factor which is of least importance, if, indeed, it is of any importance, is that of sex. Mr. R. A. Cushman, in experiments at Tallulah, La., in 1910, in which squares were under more or less uniform climatic conditions, found that 475 males averaged in development 13.88 days, while 393 females averaged 13.49 days. The figures are so nearly equal that there is great doubt as to whether the sexes require different periods.

VARIATIONS DUE TO LOCATION OF DEVELOPING STAGE.

As has been stated, the tendency of the squares to hang or fall is a determining factor in the length of the developmental stage. In a humid region, however, the difference may be very small. At Alexandria, La., in 1907, it was found that the average developmental period during the first 19 days of August in fallen squares was 15.3 days and in hanging squares was 15.1 days.

VARIATIONS DUE TO TIME OF FALLING OF INFESTED SQUARES.

The period preceding the falling of the squares to the ground seems to be one of the strongest factors in determining the length of the developmental stages. To illustrate this, at Victoria, Tex., in August, 1904, it was found that the average development in squares which hung only 1 day was 13 days, whereas for squares which hung 18 days, the development was 28½ days; also at Dallas, Tex., in August, 1906, the average development in squares which hung 6 days was 19 days and in squares which hung 22 days was 36 days. We present Table XXVII, which shows in general that the difference in the time required for development in hanging and in fallen squares is proportionately the same in all months of the year and at all places where observations have been made.

TABLE XXVII.—*Table to illustrate the effect of the time of falling upon the period of development of the boll weevil in squares.*

No. of days before falling.	Average period of development of weevils for eggs laid during specified periods.												
	Victoria, Tex., 1904.					Dallas, Tex., 1905.			Dallas, Tex., 1906.				Alexandria, La., 1907.
	June.	July 1–15.	July 15–30.	Aug. 2–11.	Sept. 10–29.	Aug. 12–28.	Sept. 11–30.	Oct. 2–3.	June 14–21.	June 29–July 6.	July 16–21.	Aug. 12–17.	July 28–Aug. 19.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1		12.0		13.0	15.0			25.0					12.5
2		13.5	13.0		13.0	13.2	18.5						12.6
3	14.4	14.0				13.4	21.7		14.5		17.0		12.3
4	14.0	14.4		16.0	15.0	14.5			16.0		15.0		13.5
5	16.0	14.1	14.8		18.0	14.7	18.7	18.0	16.3		17.0		14.9
6	18.0	15.6	17.0	15.0	19.0	16.0		26.0		17.5	17.0	19.0	14.9
7	16.6	15.5	16.0	16.6	16.6	16.6	21.2		16.3	16.0	16.9	17.9	15.0
8	17.6	18.9	17.5		18.6	16.6	28.0		17.0	16.0	17.6	19.5	16.4
9	18.6	18.3		19.6	19.5	19.0			16.0	18.5	18.7	19.5	18.9
10	30.0	18.7		25.2	22.3	19.7					18.6	21.4	17.6
11	17.0	18.8	20.6	21.5	25.5				18.6	24.0	19.2	23.4	21.2
12	23.0	20.8	21.6	22.1	22.0	19.5	28.0				18.1	24.0	
13	19.5	20.0	22.0	25.2	22.5				23.0		19.0	25.0	
14	20.0		19.0	26.1							20.5	24.8	18.0
15		22.0	24.0	23.7					23.0		19.0	25.0	
16		23.0	23.0	28.5							20.0		
17			22.0			25.0		25.0					
18				28.5	24.0							35.0	
19											29.0	36.0	
20													
21												35.0	
22				26.0								36.0	
Average	17.5	16.8	18.8	22.0	18.8	16.2	21.0	23.5	18.0	18.3	18.3	22.3	15.3
No. of stages	36	123	25	62	58	69	17	4	20	9	69	85	87

The average for the 664 stages covered in the table is 18.4 days, which may be taken as the general average period of development in squares. Figure 11 graphically illustrates Table XXVII.

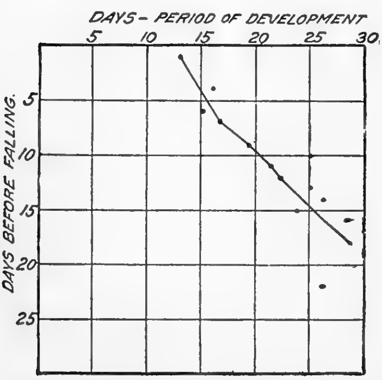

FIG. 11.—Diagram illustrating effect of time of falling of infested squares upon period of development of boll weevil at Victoria, Tex., August, 1904. (Original.)

VARIATIONS DUE TO TEMPERATURE.

It will be noticed that the average period of development in squares which have hung on the plant for the same length of time varies with the season, but an increase of temperature regularly lowers the average developmental period. The following diagram (fig. 12) has been constructed from the average curves determined for each of the stages in the development and shows that the range is from 13 days at 88° F. to 51 days at 62° F.

By using the quantities determined by the curves in figure 12 it is possible to chart the mean or normal developmental period by months for any given place with known mean temperatures. This has been done on the following diagram (fig. 13) for Victoria, Tex., Ardmore, Okla., and Vicks-

burg, Miss. The curve obtained for Victoria is the widest which can be obtained in the United States with the exception of Texas points to the south of Victoria. It is interesting, however, that

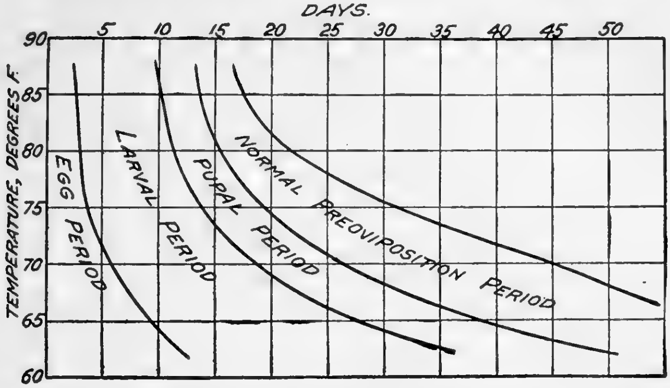

FIG. 12.—Diagram illustrating temperature control of developmental period of the boll weevil. (Original.)

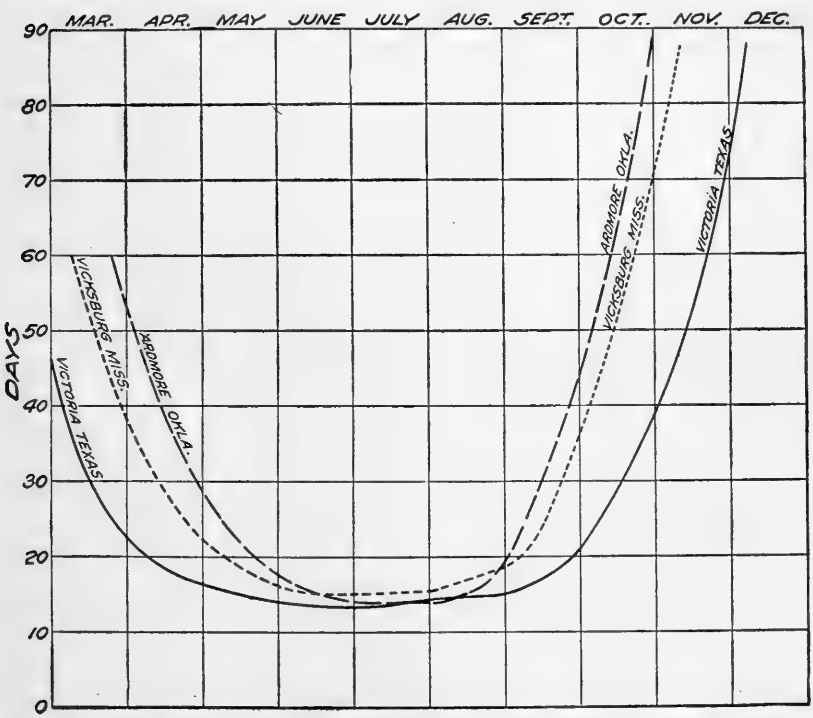

FIG. 13.—Diagram illustrating normal developmental period of boll weevil in squares, by months, at Victoria, Tex., Ardmore, Okla., and Vicksburg, Miss. (Original.)

Pensacola, Fla., would show almost as wide a curve, but there the weevil would show less rapid development in the hottest months. The Memphis, Tenn., curve is slightly wider than that for Ardmore, Okla., and Dallas corresponds almost exactly with Vicksburg. It is

interesting to note that Ardmore shows only four and one-half months in which the developmental period can be under 30 days. Adding the preoviposition period to the developmental period, it is evident that unless the weevil adapts itself to the northern conditions latitudes north of Ardmore can have only a fraction over three generations in a year, whereas Victoria, with seven months in which the developmental period is less than 30 days, frequently has six generations.

VARIATIONS OF DEVELOPMENT IN BOLLS.

It is of interest to note the variation in development in bolls due to the length of time the boll hangs on the plant. At Victoria, Tex., in June the development was 15 days for a boll hanging 1 day and 39 days for a boll hanging 26 days, while in bolls which did not drop, it frequently took over 60 days, with 67 as the maximum. The average developmental period of 67 weevils at Victoria and Dallas was 41 days, or more than twice the average period of weevils in squares. This difference may be considered as due to a combination of the factors of lower temperature, greater humidity, and less nutritious food.

MISCELLANEOUS VARIATIONS.

There are also some variations in development which can not be attributed to any of the causes cited above. Undoubtedly the insect adapts itself to the supply and condition of the food available. Consequently, under the same climatic conditions weevils in very small or delayed squares develop more quickly than those where the food is more suitable. Such variations are illustrated by Table XXVIII, which relates to the developmental periods of weevils of the third generation at Alexandria, La., in 1907.

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907.*

Date of oviposition.	Number of stages.	Total egg days.	Average egg period.	Total larva days.	Average larval period.	Total pupa days.	Average pupal period.	Total weevil days.	Average total period.
September 2	1	1	1	......	......	......	......	......	......
Do	4	4	1	24	6	......	......	......	......
Do	7	7	1	42	6	28	4	77	11
Do	4	4	1	28	7	......	......	......	......
Do	7	7	1	49	7	28	4	84	12
September 1–4	54	108	2	......	......	......	......	......	......
September 1	1	2	2	7	7	3	3	12	12
September 4	3	3	1	24	8	12	4	39	13
September 5	2	4	2	......	......	......	......	26	13
September 3	2	4	2	10	5	12	6	26	13
September 4–5	10	20	2	60	6	50	5	130	13
September 1–5	30	60	2	210	7	120	4	390	13
September 2	5	5	1	20	4	45	9	70	14
Do	16	16	1	112	7	96	6	224	14
Do	4	4	1	40	10	16	4	56	14
Do	12	24	2	72	6	72	6	168	14
September 3–4	3	6	2	21	7	15	5	42	14
September 2–4	18	36	2	144	8	72	4	258	14
September 2	9	18	2	81	9	27	3	126	14
August 31	14	42	3	......	......	......	......	......	......
Do	3	9	3	......	......	......	......	42	14
Do	3	9	3	24	8	24	3	42	14
September 1	2	4	2	14	7	12	6	30	15
August 31	4	12	3	32	8	16	4	60	15
September 1	6	12	2	42	7	42	7	96	16
August 31	2	6	3	16	8	10	5	32	16
Do	3	9	3	24	8	18	6	51	17
August 26	3	......	......	......	......	......	......	57	19
Do	3	......	......	......	......	......	......	60	20

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907*—Continued.

TOTALS AND AVERAGES.

Date of oviposition.	Number of stages.	Total egg days.	Average egg period.	Total larva days.	Average larvel period.	Total pupa days.	Average pupal period.	Total weevil days.	Average total period.
Egg period	229	436	1.9						
Larval period	149			1,096	7.3				
Pupal period	141					717	5.0		
Total period	152							2,198	14.4

DEVELOPMENT OF WEEVILS IN THE SQUARES WHICH NEVER FALL.

It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. The form of the absciss-layer grown when the square is injured determines whether it is to fall or to hang. (See Pl. XV.) This will be explained fully in connection with the discussion of parasites (pp. 143, 144).

Certain climatic and cultural conditions seem to increase the tendency of the cotton plants to retain the infested squares, although this tendency seems to be very largely of a varietal character. In the hanging position the square dries thoroughly and becomes of a dark-brown color. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not destroyed by the sun in the same proportion as those which are exposed to the sun on the hot soil. However, control by parasites is much greater in the hanging squares than in the fallen squares—so much greater at times that the total mortality from all causes in hanging squares surpasses that of fallen squares. This matter will be dealt with more fully in a later section.

Owing to the much smaller number of squares which hang on the plants, we have been unable to obtain a sufficiently large series of records upon the development of the weevil in this class of squares, but the records available show that the development is slightly shorter in hanging squares than in the average fallen squares.

DEVELOPMENT DURING WINTER.

As is normal with many species of weevils, there is some development during the winter months. This development, however, is frequently cut short by severe freezes. In southern Texas larvæ and pupæ of the boll weevil which are in squares when frost comes are not always killed thereby, but slowly finish their development if the weather is warm enough for any activity, and the adults thus developed may live through the winter without feeding. Mr. J. D. Mitchell took a number of live larvæ, pupæ, and adults from bolls in a field at Victoria, Tex., on December 26, 1903, after two hard frosts and one freeze. Two weeks later, from a field in the same locality, after three hard frosts and two freezes (30° F.), he took another lot of live specimens in these three stages. On February 7, 1904, Mr. Mitchell took 32 adults, 1 pupa, and 4 larvæ, all alive, from standing stalks, and on February 14 he found 32 adults, 2 pupæ, and no larvæ. The material collected at different times up to February 14

included 197 specimens, 23 larvæ, 30 pupæ, and 144 adults. It is therefore evident that large numbers of weevils go into the winter in the immature stages, and there is every probability that, in the southern part of Texas at least, many of them live and mature, emerging in the spring. It may be that this gradual maturity of the hibernated weevils is one of the reasons why they emerge so irregularly from their winter quarters.

Prof. Sanderson, in Bulletin 63 of the Bureau of Entomology, mentions that in March, 1903, Mr. W. P. Allgood sent him from Devine, Medina County, Tex., a quantity of bolls, which were examined March 12. Twenty per cent of the bolls contained weevils, alive or dead, in some stage. In 40 bolls there were 40 live and 11 dead pupæ, 30 live and 40 dead adults, and 5 dead larvæ. Many of the adults had just transformed from pupæ. One live larva was found in the material. Estimating the survival of weevils in the plants in this field, Prof. Sanderson calculated that there would be about 10,500 weevils per acre in the spring. The lowest temperature which the weevils experienced in the locality from which these bolls were sent was 23° F. in February.

SEASONAL ABUNDANCE.

BROODS OR GENERATIONS.[1]

The term "brood" can hardly be applied in its usual sense to the generations of the weevil, as was pointed out by Dr. L. O. Howard in the first circulars of the bureau dealing with the problem. For several reasons no line of distinction can be drawn between the generations in the field at any season of the year, not even between hibernated weevils and the adults of the first generation. As has been shown, the period of oviposition among hibernated females is in some cases fully 3 months, while it averages 48 days. The average period of the full life cycle for the first generation is 25 days, and as the time for the second generation would be slightly less, it is evident that the first eggs for the third generation may be deposited at the same time as those for the middle of the second generation, and also with the very last of the eggs deposited by hibernated females for the first generation, as shown in figure 14. The great overlapping of generations thus produced prohibits the application of any of the common methods of ascertaining their limits. The complexity indicated for the first three generations becomes still further increased as the season advances, so that in October, for example, a weevil taken in the field might possibly belong to any one of five or six generations. Duration of life and the period of reproductive activity are important factors in determining the average number of generations. Periods of greatest abundance can not be regarded as giving any reliable information upon this point, since the number of weevils developed soon comes to depend largely upon the supply of squares.

In the case of the boll weevil, therefore, the information upon the number of generations must be drawn mainly from laboratory sources, but the results are supported by observations made in the field. Many of the hibernated weevils continue to deposit eggs until the middle of July, and some are active for fully a month longer. In 1903 the last eggs from hibernated weevils were deposited on August 27. In the course of rearing experiments made in 1902 it was found that many

[1] The following two paragraphs are taken from Bull. 51, Bureau of Entomology, pp. 95, 96.

weevils which had become adult about the 1st of August would continue to deposit eggs until the latter part of November. Considering the longest-lived weevils and their last-laid eggs, therefore, it is easily possible for two generations to span the entire year. The weevils developing after the middle of November may go into hibernation, and from their last deposited eggs produce weevils whose last offspring will be ready for successful hibernation again. This conclusion is based upon actual demonstration.

The maximum number of generations will be found by taking the first instead of the last eggs deposited in each case. In order to ascertain the maximum number of generations which would be possible, the figures for the development at Victoria, Tex., have been taken. Figure 14 is a diagram which shows the maximum number of generations possible and also the minimum number possible. This is based upon the mean temperatures of the various months at Victoria and the known period of development at such mean temperatures. The maximum number of generations of course begins with the first egg laid by the first weevil to begin oviposition in the spring and continues with the first egg of the first developing weevil from each generation. In this manner it will be seen that 10 generations are possible for weevils reared on squares. The last egg laid by the first emerged weevil and the last eggs laid by the following generations allow only three generations from the first emerged weevils, which might be considered the minimum. The maximum number of generations from the last emerging weevils by the same system can only be eight generations, whereas the minimum number of generations from the last emerged weevils will be two generations.

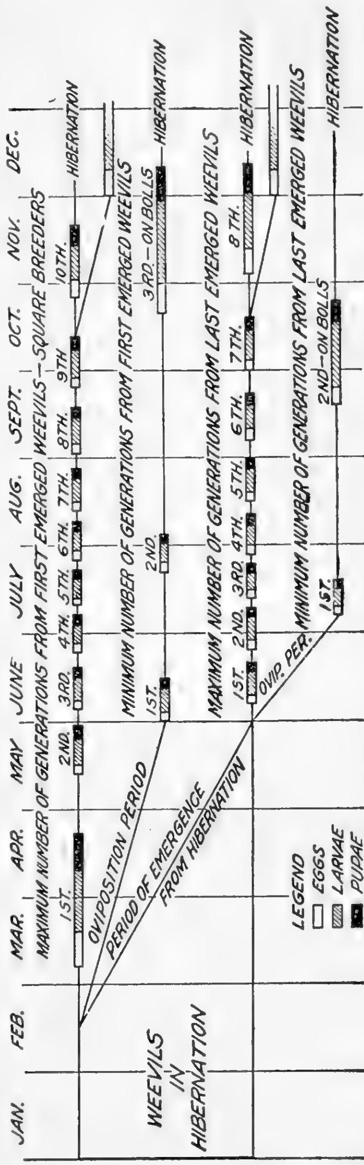

FIG. 14.—Diagram illustrating seasonal history of the boll weevil at Victoria, Tex. (Original.)

There is no basis for the idea that there is a distinct hibernation brood. The activity of the adults and the development of the immature stages is gradually retarded by the decline in temperature until

hibernation time arrives. Most of the weevils of the first two or three generations have probably died, or then do so, while most of the adults of later generations, still having considerable vitality, go into hibernation. It is certain that every generation may have some direct part in the production of weevils which are to hibernate. All weevils which are still strong and healthy when cold weather comes on may be expected to go into hibernation, so that there can be no special brood for this purpose.

POSSIBLE ANNUAL PROGENY OF ONE PAIR OF HIBERNATED WEEVILS.

One of the most important factors in the development of an insect is its capacity for very rapid production. The conclusions as to the ability of the boll weevil in this respect are drawn from the following data, summarized from what has been set forth in preceding pages of this bulletin. The starting point is considered to be the average date of deposition of one-half of the eggs for the first generation at Victoria, Tex., which, under the usual conditions, seems to be about June 10. The average number of eggs deposited by a female was found to be 139. For the purpose of this computation 70 is the assumed number. The difference may be considered as an allowance for mortality or failure to hatch. The average period of development for each generation is 19 days. The average period between emergence of the adult and deposition of the first eggs is 6 days. The average period for the deposition of one-half the eggs for each generation is 18 days, thus making the average period for each generation 43 days. The sexes are produced in approximately equal numbers. For the sake of conservatism allowance has been made for only four generations in a season. The following table shows the rate of multiplication and the corresponding dates:

Annual progeny of one pair of hibernated weevils.

	Weevils.
First generation, average adult June 29, numbering	70
Second generation, average adult Aug. 10, numbering	2,450
Third generation, average adult Sept. 22, numbering	85,750
Fourth generation, average adult Nov. 4, numbering	3,001,250
Total	3,089,520

As a matter of fact, the multiplication during the early part of the season is so much more rapid that it is very certain that a large part of the third generation becomes adult by the middle of August. Possibly a more definite idea of the significance of this ability for reproduction may be obtained if we consider that, at the conservative rate given, the progeny from one fertile hibernated female might, in the course of four generations, number one weevil for every square foot of area in a 75-acre field.

As a matter of fact, the possibility of the multiplication is controlled primarily by the abundance of food supply. The maximum infestation is usually reached some time in August. If we assume that there are 6,000 plants on each acre of ground, and that each plant produces 100 squares for weevil attack up to August 1, we would find that if the usual percentage of these squares produces weevils, the actual

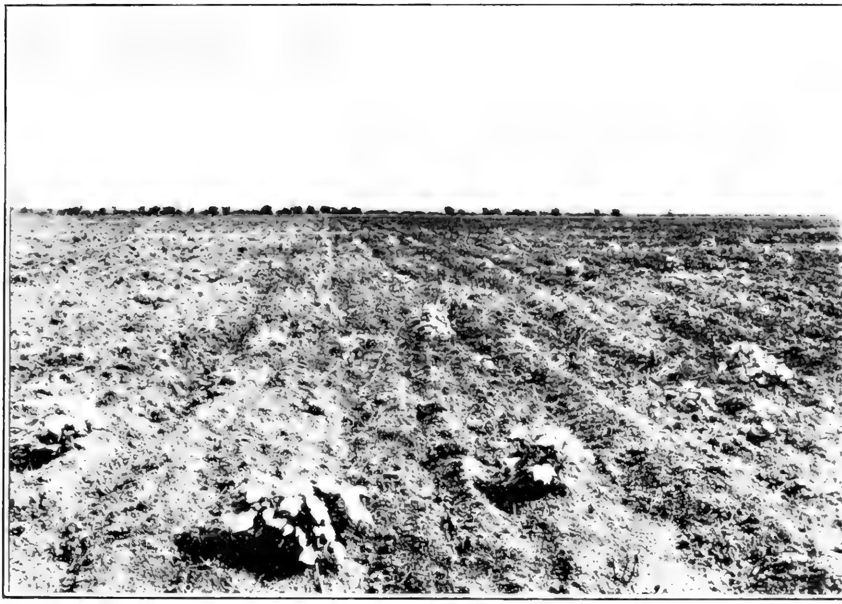

Fig. a.—Newly planted cotton field, with sprouts from overwintered cotton roots. (Original.)

Fig. b.—Fallen infested squares. (Original.)

FIELD CONDITIONS IN TERRITORY OCCUPIED BY THE BOLL WEEVIL.

multiplication would be limited to about 250,000 weevils per acre. It has been shown in this bulletin that on the average over 50 per cent of the weevil stages are destroyed by natural conditions. This means that the theoretical possibilities are never reached. In fact, it is doubtful whether the actual increase from a single pair exceeds 2,000,000.

Prof. Sanderson, in Bulletin 63, of this bureau, estimated that the actual increase in the number of weevils from the 1st of June to the 1st of September is about 50 times and certainly not over 65 times, where theoretically it would be 625 times.

PROGRESS OF INFESTATION IN FIELDS.

It is of considerable importance to understand the rate of increase of the infestation in the fields. Normally, in a given cotton field the infestation when the squares have just begun to form is under 10 per cent, but this percentage increases very rapidly in proportion as the hibernation was successful. The infestation generally starts in a given field in the vicinity of timber or of buildings where cotton or cottonseed was stored during the winter. It then progresses in increasing circles until the entire field is scatteringly infested. From then on the increase is general until it is almost impossible to find an uninfested square. Table XXIX may be used to illustrate the progress of infestation in a given field.

Table XXIX.—*Progress of infestation by the boll weevil, field 1, Victoria, Tex.*[1]

Block.	Date.	Number of squares examined.	Number of squares infested.	Percentage.	Remarks.
	1903.				
I	June 8, 9	4,200	675	16.0	Work of hibernated weevils only.
I	July 13	467	211	45.0	Second generation at work.
I	July 22	249	193	77.5	Third generation beginning.
I	August 4	278	224	80.6	
I	August 29	91	85	93.5	About four generations now working.
II	July 30	358	168	46.6	Much cotton dying from root rot.
II	August 1	331	148	44.7	
II	August 4	300	100	33.3	
II	August 20	699	636	91.1	
	Total	6,973	2,440	35.0	

[1] From Bull. 51, Bureau of Entomology, p. 114.

Additional illustrations are furnished in Table XXX.

TABLE XXX.—*Observations upon infestation by the boll weevil, various localities, 1904.*[1]

Locality (Texas).	Number of plots under examination.	Number of examinations made.	Period covered.	Total squares examined.	Average percentage of squares showing weevil attack.	Total number of weevils taken with squares.	Average percentage of squares containing weevils.	Total number of small bolls examined.	Average percentage of small bolls attacked by weevils.	Average percentage of squares showing attacks by other insects.	Average percentage of clean squares.
Calvert	12	2	1904. Aug. 23 to Sept 9.	2,754	94.0	251	9.1	1,175	94.7	1.8	4.2
Corsicana:											
A	12	5	July 29 to Sept. 12.	6,951	72.4	376	5.7	2,506	71.9	.6	27.0
B	11	5	July 28 to Sept. 12.	4,534	80.4	407	9.0	3,261	64.9	.6	19.0
Mexia	15	5	July 30 to Sept. 13.	6,445	64.4	317	5.0	4,618	64.9	1.2	34.5
Palestine	22	2	Aug. 26 to Sept. 14.	3,719	91.3	274	7.4	2,456	92.8	.7	8.2
Victoria	11	18	June 18 to Sept. 24.	13,227	54.2	170	1.3	544	66.9	6.1	44.6
Wharton	4	4	July 22 to Aug. 25.	5,005	65.0	167	3.3	230	46.4	10.2	25.3
Total	87		June 18 to Sept. 24.	42,635		1,962		14,790			
Average		6			70.1		4.6		80.0	2.2	27.7

[1] From Bull. 51, Bureau of Entomology, p. 116.

Prof. Sanderson[1] has estimated that usually 50 per cent of the squares will be punctured by about two months after the cotton commences to square, at which time there would normally be about 100 squares to the stalk. When one-half of the squares are punctured it may be readily concluded that there are probably sufficient weevils present to prevent any more squares from forming fruit. It will be seen, therefore, that the critical period in the relation between natural increase of squares on the plant and increased injury by the boll weevil is during the period of six to eight weeks after the first squaring, which usually coincides more or less closely with the time between the appearance of the second and third broods of the weevils. Thus, if we consider six weeks as the average time for cotton to begin to square after planting, it will be seen that the bulk of the fruit must be set in 85 or 95 days after planting. In other words, to escape injury by the boll weevil, cotton must be so grown that the bolls will commence to open in about 100 days after planting and that all the fruit which will probably be secured must be set within 45 days after the squares begin to form. The advantage of early planted cotton and rapid-maturing varieties becomes, therefore, very apparent.

Field examinations have shown that the period of maximum infestation is reached between August 1 and 20, and that from 6,000 to 10,000 adult weevils per acre is sufficient to cause maximum infestation within a few days. The highest number of weevils per acre which has ever actually been recorded from a locality during the summer was

[1] Bull. 63, Bureau of Entomology, p. 38.

24,347 adult weevils at Port Gibson, Miss., in August, 1911.[1] With this number of weevils there was a record of only 37.03 per cent infestation of the remaining squares and bolls. Higher percentages of infestation have been recorded with much smaller numbers of adult weevils per acre.

EFFECT OF MAXIMUM INFESTATION UPOM WEEVIL MULTIPLICATION.

At the time of maximum infestation the majority of the third-generation weevils are becoming adult and many of the hibernated weevils have died. About this time also a decrease in square pro-

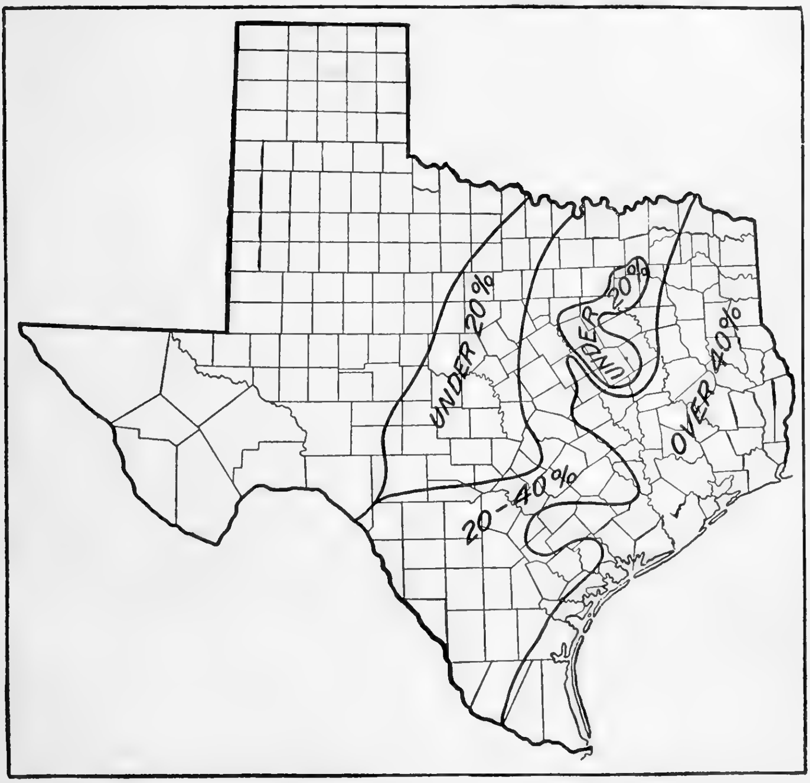

FIG. 15.—Status of the boll weevil in Texas in August, 1906; percentage of infestation of all forms. (Original.)

duction accompanies the maturity of the bulk of the crop, owing to the fact that the assimilative power of the plant is largely consumed in maturing seed. If dry weather occurs at this period, which is frequently the case in Texas, there is a further decrease in the number of weevils present. Not only are there fewer squares to become infested, but each square is also subjected to greater injury, and many which would otherwise produce weevils are unfitted as food for the larvæ by the decay which follows the numerous punctures. Several eggs may be deposited in each square, but as a rule only one weevil

[1] During the late fall the number may be much larger. See p. 76.

will develop. These general conditions frequently bring about a reduction of the number of weevils present in the field. This becomes evident to the planter by the number of blooms seen. Of course, the conditions soon change and the weevils become more abundant than before.

STATUS EXAMINATIONS.

In order to become fully acquainted with the conditions of the weevil during the most important parts of the season, it has been the custom to conduct an extensive series of observations in the latter part of

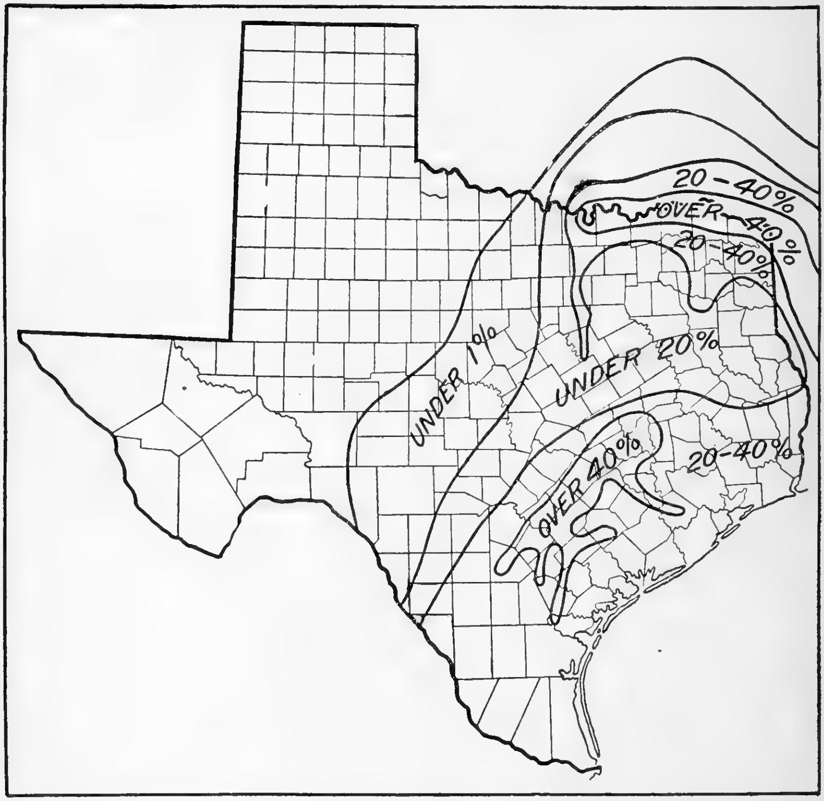

FIG. 16.—Status of the boll weevil in Texas in August, 1908; percentage of infestation of all forms. (Original.)

June and first part of July and again in the first half of August in order to learn the extent of damage being done by the weevil. These examinations have been made so thoroughly and have been distributed in such a manner that it has been possible, even in June, to determine the probable direction of the greatest movement of the weevil during the season, to point out the regions in which the damage to the crop will be greatest, and also to indicate where the control of the weevil during the winter has been of greatest consequence. The first "status" of the year frequently gives very definite evidence of natural control or an absence of it. While certain general methods of

control have been contrived, it is still true that some of the most important methods of control are those which are devised to suit particular emergencies. These have been indicated from time to time in connection with the status reports.

RELATION OF WEEVILS TO TOP CROP.

After considerable cotton has been matured fall rains often stimulate the production of a large number of squares, and many planters are misled by the hope of gathering a large top crop from this growth.

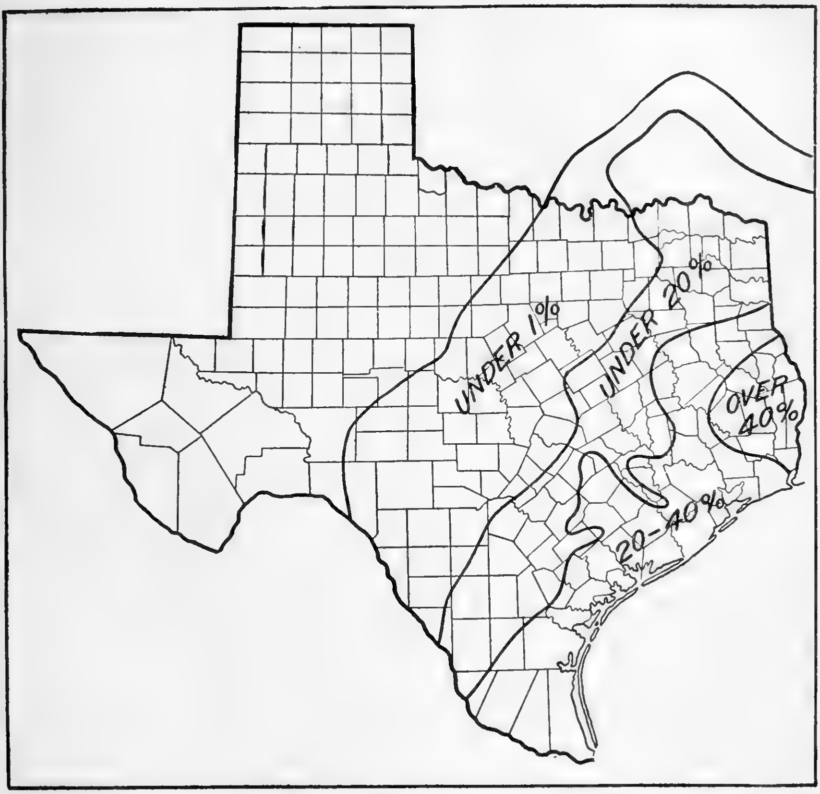

FIG. 17.—Status of the boll weevil in Texas in August, 1909; percentage of infestation of all forms. (Original.)

The joints of the plant are short, and the squares are formed rapidly and near together. Though weevils may have been exceedingly numerous in the fields, their numbers will have become so decreased by the dispersion and by the limited quantity of food that they can rarely keep up with the production of squares at this period of rapid growth. Many blooms may appear, and the hope of a large top crop increases. It has been a very rare occurrence that planters have gathered top crops, even in years of no injury from insects.

The chance of its development, though always small, becomes practically inconsiderable wherever the weevil is present in numbers.

In the senior author's experience of 10 years only one example of a top crop in a weevil district has been seen. This happened in the vicinity of Brownsville, Tex., in 1911. The production of a few bolls on the tops of the plants was due to a rare combination of exceptional influences, including very dry weather during the summer, defoliation at an early date by the cotton worm, and late rains after the weevils were greatly reduced in numbers.

Neither the very remote chance of gathering a top crop nor the actual injury which is being done to the crop of the succeeding year by allowing that growth to continue until frost kills it is generally

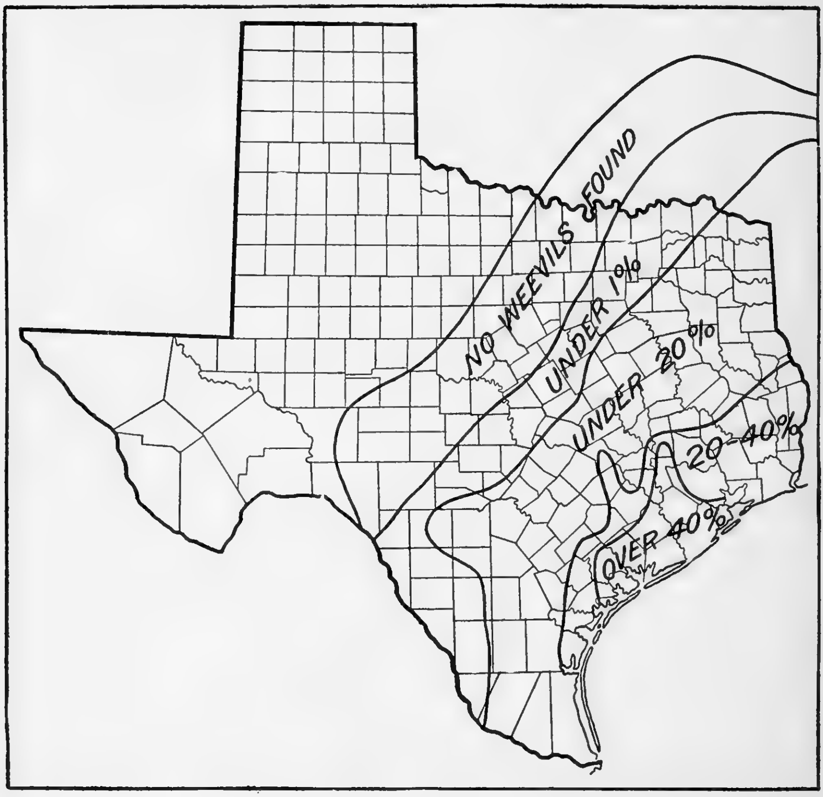

FIG. 18.—Status of the boll weevil in Texas in August, 1910; percentage of infestation of all forms. (Original.)

appreciated by planters. Because of the apparent abundance of squares and the presence of many blooms the plants are allowed to stand long after they might have been destroyed to the great benefit of the next crop. As is the case in the early spring, however, the abundance of squares increases greatly the production of weevils, and though a few bolls may set, they are almost certain to become infested before they reach maturity. Every condition, therefore, contributes to the production of an immense number of weevils very late in the season and at just the right time for successful hibernation. As a result, far greater injury is done to the crop of the following

season with no actual gain in the yield of the current season. Plants standing until frosts kill them are often allowed to remain throughout the remainder of the winter and easily furnish an abundance of favorable hibernating places for the weevils. The consequence of this practice is that so many weevils are carried through the winter alive that the yield of the next year is much less than it might have been but for the farmer's indulgence of the forlorn hope of a top crop. It is far wiser to abandon the uncertain prospects of a top crop and destroy the stalks in order to insure a better crop the following year.

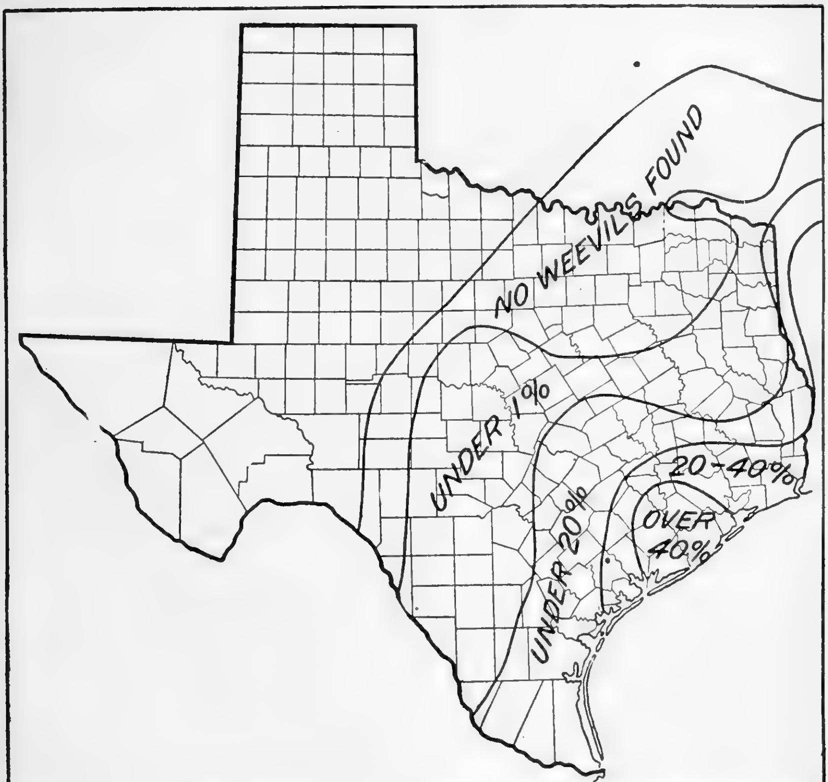

FIG. 19.—Status of the boll weevil in Texas in August, 1911; percentage of infestation of all forms. (Original.)

VARIATIONS IN ABUNDANCE OF THE WEEVIL FROM YEAR TO YEAR.

The decrease in damage by the weevil in Texas in the last few years has led some observers to believe that the insect will finally disappear altogether. Investigation shows that this belief is erroneous. In 1897 the French entomologist, Dr. Paul Marchal, published a paper which set forth some of the essential factors governing insect abundance from year to year. This author called attention to the more or less regular periodicity in the abundance of certain well-known injurious insects. In this country the cotton leaf worm, *Alabama argillacea* Hübner, is an example of such periodical abundance. The

application of Dr. Marchal's law to the abundance of the boll weevil will be discussed in the following paragraphs.

When the boll weevil entered the United States, it was released from most of its natural enemies and was in the portion of the cotton belt most resembling its natural home. Naturally, it increased with great rapidity. In fact, the weevil was on what may be called the upward curve of numerical abundance from 1892 to 1896. In the meanwhile, native parasites began to adapt themselves to it, and we may assume that their abundance might be indicated by a curve parallel to but behind that of the boll weevil. In 1896 a severe drought was the cause of a very sudden decrease in the numbers of the weevil and of course also acted upon the parasites. Following 1896 the increase in abundance of the weevil was comparatively slow, owing to the unlimited opportunities for spread. The maximum point in this increase appears to have been reached in the autumn of 1904 and may have been partly due to the fact that in that year the abundance of the parasites was on the decrease. In the winter of 1904 a severe cold period turned the curve of abundance downward, but the decrease was slow until the fall of 1907, when another severe freeze caused a sudden falling off. Floods in the spring of 1908, drought in the summer, a freeze in the fall of the same year, and droughts in the summers of 1909, 1910, and 1911, followed in 1909 and 1910 by severe winters, all combined to reduce the weevil still more. On the other hand, from 1904 to 1908 the influence of the parasites was increasing and from then until 1911 decreasing. As Dr. Marchal pointed out, it is very rare that some condition does not intervene just before the number present has reached zero and save the species from extermination. The weevil will undoubtedly frequently be greatly reduced in large regions, but in such areas the inflow from other localities will serve to bring about early reestablishment. (See fig. 20.)

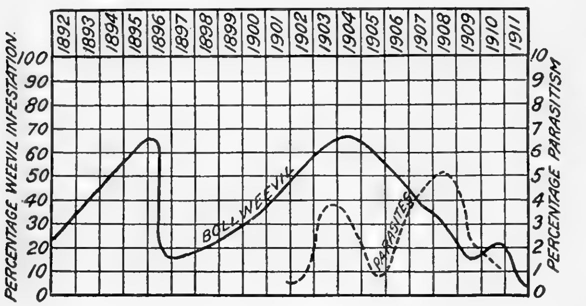

FIG. 20.—Curves of numerical strength of the boll weevil and its parasites. The boll weevil curve is at the scale of 2 to 10 and represents the percentage of infestation in August in Texas. The parasite curve is at the scale of 1 to 1 and represents the percentage of mortality of the boll weevil due to parasitism. (Original.)

Undoubtedly the adverse seasons of recent years will be followed by others which will allow the weevil to reach approximately its former abundance. This alternation of years of scarcity and of abundance will continue indefinitely. Naturally, no definite prediction can be made as to the number of years which will be included in the alternating periods.

The series of Texas maps presented herewith (figs. 15–19) illustrates the variations in the percentage of infestation in August during a series of years in which the weevil abundance was at a low ebb. They also show very plainly how the areas of heavy damage are shifted by more or less local causes.

The status examinations upon which these maps were based show the following average percentages of infestation in Texas. (See Table XXXI.)

TABLE XXXI.—*Percentage of infestation by the boll weevil in Texas in August; years 1906 to 1911.*

Year.	Percentage of infestation.
1906	50.11
1907	38.09
1908	32.32
1909	14.78
1910	20.79
1911	1.12

NATURAL DISSEMINATION.

The natural movements of the boll weevil are of several more or less distinct kinds. For several months in the spring there is a general dispersal in search of food. After the cotton commences to square there is a steady spread across the fields from the vicinity of the places where the insects have hibernated. This may become a spread from field to field. In late summer there is a sudden and wide dispersal, which is shortly followed by a search for hibernation.

SPRING SEARCH FOR COTTON.

After a quiescent period of from five to eight months the weevils leave their hibernation quarters and start in search for food. During a warm period, such as was experienced in March, 1907, many weevils come out of hibernation long before any cotton has made its appearance. Without doubt these weevils wander considerable distances and finally either die or reenter the quiescent state on account of lower temperatures. As the emergence from hibernation covers a period of about three months there is little or no regulation of the direction of flight, such as might occur if all emerged at the same time during a high wind. Elaborate tests have been made by releasing marked weevils fresh from hibernation in the vicinity of cotton fields. Invariably after careful search a very small percentage of these weevils have been found in the nearest cotton.

The experiments of Mr. A. C. Morgan in 1906 at Victoria, Tex., give the most specific data on individual flight. Seven hundred and eleven weevils were used in the experiments, of which 355 had been fed and 356 were unfed. Of the fed weevils 179 were male and 176 female, while of the unfed weevils 183 were male and 173 female. This gave a total of 362 male and 349 female weevils. The maximum flight by a fed male was 775 yards, by a fed female 350 yards, by an unfed male 225 yards, and by an unfed female 500 yards. The experiments also showed the average distance per 24 hours for a fed weevil as 63.3 yards, and for an unfed weevil, 66.6 yards. It was generally observed that the weevils flew with the prevailing wind.

Observations on the early spring movement of the weevil in Mississippi in 1910 showed the utility of the rotation of crops. During

the two status examinations made in 1910 in southern Mississippi it was very evident that in these fields in which cotton followed corn there was a conspicuous absence of infestation until the fall dispersion of 1910, whereas in neighboring fields in which cotton followed cotton the infestation was in some cases extremely high, even in June.

These circumstances and many others which have been observed in the spring indicate a rather irregular dispersal from the places of hibernation which may carry the weevils considerable distances in all directions. On the extreme border of the infested territory this may result in the infestation of entirely new territory.

SPRING SPREAD WITHIN THE FIELD.

The spread from plant to plant begins in the portions of the field adjacent to favorable hibernation quarters. It has usually been found that the early summer infestation begins at a point adjacent to timber or near farm buildings where seed or seed cotton has been stored. From these centers it is generally easy to trace the infestation to other parts of the field. The movement of the weevils from these centers, however, is not regular. They occasionally fly to rather distant portions of the field and then start new centers, but on the whole the progress is steady and soon brings about a complete infestation of the field.

A number of observations were made to determine the degree of movement of hibernated weevils in a field at Victoria, Tex., in 1904. The weevils were marked so that they could be recognized, and frequent examinations were made to determine the location of each specimen from day to day.[1] It was found that the maximum time one weevil remained upon a single plant was 18 or more days, the observations having been discontinued after the eighteenth day. The average time positively found in 73 cases was 4 days, with a possibility for this same number of observations of $6\frac{2}{3}$ days. Probably a true average lies approximately between these results, and, if so, we may assume that about $5\frac{1}{3}$ days usually intervene between the movements of each weevil. In the whole series of observations, extending over 25 days, for weevils which were found after being liberated, only 57 movements were recorded. The total of these movements averaged only 62 feet each in 177 movement days. This would give us an average movement of but 0.35 foot per day for each weevil in a field where stubble plants were quite abundant, where squares were forming upon fully one-third of the plants, and during a period for which the mean average temperature was 78.6° F.

SUMMER FLIGHTS.

During the summer there is more or less general movement within the cotton fields and also from field to field. These flights are at first weak, but gradually become more pronounced and finally lead into the great dispersal of the late summer and fall.

During the summer the conditions on the border of the infested area are peculiar. Many of the weevils which arrived late in the fall of the preceding year are unable to survive the winter on account of

[1] The remainder of this paragraph is from Bulletin 51, Bureau of Entomology, p. 112.

their exhausted condition. Therefore, the line of continuous infestation may be considerably behind the line of continuous infestation resulting from the last movement of the preceding year. Outside of this continuous line is a strip of considerable width in which the weevil is found scatteringly. The summer flights cause these isolated infestations to coalesce.

FALL DISPERSION.

All movement of the weevil at other seasons is insignificant in comparison with the great dispersion of the fall which carries the insect far into new territory. It is this movement which causes the more or less regular annual advance in the cotton belt. In one sense this dispersion is merely an overflow from territory in which the insects have become so numerous that there remain no opportunities for breeding. In another sense it appears to be the result of a strong instinct which the weevils possess to invade new regions. At any rate, they show great activity in the late summer and fall. The main causes of the fall flight, therefore, appear to be (1) a scarcity of food and breeding places due to maximum infestation, and (2) an instinct to invade new territory. Several conditions may tend to precipitate the movement or strengthen it. Among these are damage by other cotton insects, which hastens maximum infestation, and drought, which may have the same effect by preventing the continued fruiting of the plants.

There seems to be no special tendency to fly in any particular direction, although prevailing winds frequently cause the majority of the insects to follow one course. This has been observed to be southeast, north, and east in different localities. If not governed by the wind, any weevil which takes flight is as likely to fly toward the old infested territory as in any other direction. It is, therefore, only a portion of the dispersing weevils which enlarges the infested territory.

The distance any weevil will fly in this movement depends upon how soon it finds uninfested cotton. If on the first flight it finds only heavily infested cotton or none at all it will take wing again. In this way a succession of flights may carry the insect over a wide territory. In one case a distance of over 40 miles has been known to be covered in this manner. If, on the other hand, the first flight carries the weevil into an uninfested field it remains there. Consequently, the advance is slowest in regions where cotton fields are numerous. The occurrence of the leaf worm, *Alabama argillacea*, in great numbers in any locality destroys the food and tends to cause decidedly longer flights of the dispersing weevils.

So far as we have been able to discover, the weevil has no sense by which it can locate cotton. Such a sense may exist, but the general aimless flight of thousands upon thousands of individuals seems sufficient to account for the infestation of all fields in new territory. An interesting observation was made by the junior author and Mr. G. N. Wolcott near Meridian, Miss., that the early dispersing weevils, in flying through hill country with heavy woods, found only the patches on the tops of the hills and from these gradually spread downward to the denser cotton.

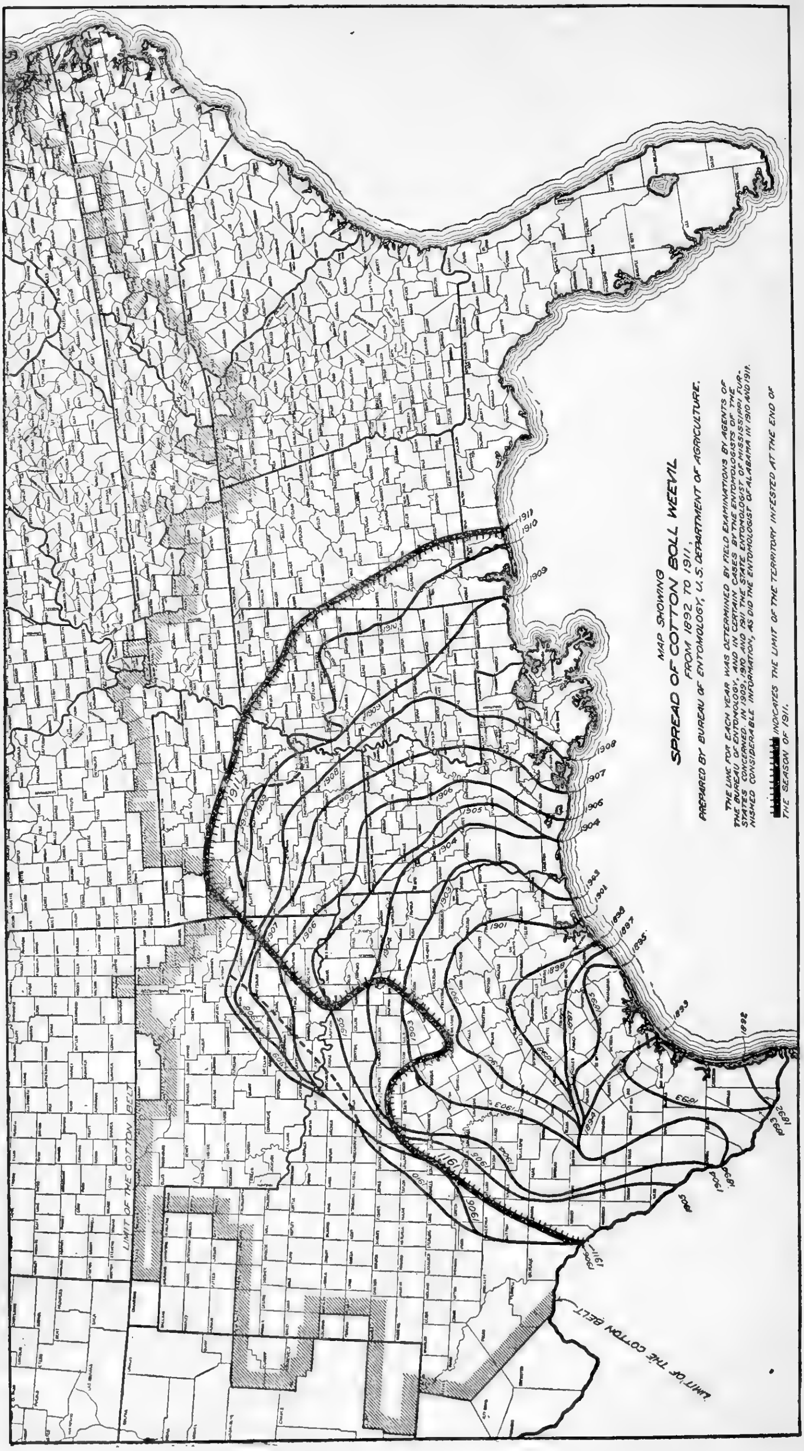

FIG. 21.—The spread of the cotton-boll weevil from 1892 to 1911. (From Hunter.)

The fall movement of the weevil has been studied carefully each year since 1904. (See fig. 21.) The circumstances have been different each season, but with uniformity within certain limits. Several examples will be given. In the fall dispersal of 1904 the weevils seemed to have crossed the line of continuous infestation in southern Louisiana about August 1, and a little later toward the north, but in all cases the movement had crossed the line by the 20th of August. In this year there were two very well-defined dispersals with about a month intervening. This might indicate that the first dispersal was caused by the lack of food and that in another month a new generation found itself confronted by the same conditions as its predecessor and was also forced to disperse.

In 1906 the movement seems to have been more irregular, for the first serious new infestation was in central Louisiana rather than in the southern part of the State. In the light of present knowledge this was probably due to the smaller amount of cotton grown in the pine woods of southern Louisiana, which naturally gave rise to comparatively few weevils for the flight. The year 1906 was the last in which any appreciable movement into western Texas was observed until 1910.

In 1907 and 1908 the eastward and northeastward progress of the weevil carried it far into regions where much cotton is produced. The year 1909 exhibited some very striking features. There had been a considerable loss in the infestation during the winter of 1908 in northern Louisiana and eastern Arkansas, a region of very extensive cultivation of cotton. During the autumn of 1909 the almost continuous movement in southern Mississippi from field to field in the rather sparsely cultivated areas amounted to 120 miles for the season. In the delta region of Louisiana, Mississippi, and Arkansas, where the weevils encountered a belt of extensive cotton culture from which they had been driven back during the previous winter and were stopped by the large amount of food available, they were unable to gain more than 20 miles of new territory.

In 1910 a peculiar situation developed. It was discovered that high winds had caused an extensive movement into central Mississippi in May or June. In the entire history of the weevil there had previously been known but one occasion when a severe storm caused a dispersal of the insect. A study of the records of the Weather Bureau brings out the fact that there was a series of cyclonic storms about May 7, 1910, passing northeastward across Mississippi from the heavily infested regions around Natchez. We have been unable to find any other explanation of such an extensive movement in the early spring. Studies conducted during the summer and fall of 1910 revealed the existence of many sporadic infestations throughout central Mississippi, probably due to the storm. From these isolated infestations the weevils spread in concentric circles until about the end of November, when the intervening territory became covered.

The winter of 1909–10 was unfavorable to the weevil in the Delta. When the dispersion season opened it was noticed that in strong contrast to the rapid movements in central Mississippi, the weevils in the Delta advanced slowly. During the entire season there were only two courses of considerable movement in the Delta region. One of these was along the Mississippi River through the fields adjoining the levees. The other extensive movement in the Delta country

was in a belt coincident with a strip known locally as the "dogwood ridge."

The winter of 1910–11 also was unfavorable to the weevil. It began with a sudden freeze on October 29, which extended over almost the entire infested region and destroyed the food supply. Severe cold weather in January also contributed to the control. Examinations made in June and August, 1911, demonstrated that the weevil was in the lowest average condition numerically that it had ever reached. It was completely exterminated in the northern portion of the Texas and Oklahoma black prairie, but west of this was a region which escaped the first frost, and where the weevils occurred in more or less normal numbers.

The defoliation by the leaf worm was so widespread that a condition of maximum infestation was reached with much smaller numbers of weevils than usual, and the scarcity of proper food supply forced a phenomenal advance along the Mississippi River toward Tennessee.

In Texas and Oklahoma there were some gains made in the lost territory, but even with these gains 24,000 square miles of territory were not reinfested. The northern limit of cotton production in western Arkansas was reached, and the line of infestation stopped only about 10 miles short of the southwestern corner of Tennessee. Great gains were made in northern Mississippi, and western Alabama and Florida became invaded for the first time.

HIBERNATION FLIGHT.

The fall dispersion movement continues more or less regularly until frosts occur and mark the beginning of the hibernation period. Thus, in many cases the fall dispersion is a flight into winter quarters. However, a period of feeding seems to be necessary for successful hibernation. Therefore, few of the dispersing weevils which are forced into hibernation by cold weather survive. Those that do survive seem to be supplied from a distinct movement into hibernation quarters at the end of the season. The most striking observation on this point was made by Mr. J. D. Mitchell in the winter of 1906. Although there had been no lowering of the temperature, he found on entering the cotton fields on November 18 a very restless activity among the weevils. Adults were observed upon the squares with their wings open and flew at the least disturbance. He observed many hundreds of weevils rising into the air and disappearing. The weather was warm and pleasant, and there appeared no reason at the time for this flight, which continued for about two days. In a few days the temperature became decidedly lower, and Mr. Mitchell was able to find only a very few weevils remaining in the fields. This note is of special interest in connection with the observations on climatic control, which will be discussed later.

OTHER FORMS OF NATURAL SPREAD.

Heavy windstorms, hurricanes, and cyclones are powerful agents in the spread of the weevil. It is believed that the great storm of September 8, 1900, in Texas, carried the infestation northward many miles. As has been stated, the storms of about May 7, 1910, in Mississippi, were instrumental in causing a considerable increase of the infested territory in that State.

There is another method of natural spread of some local importance. In hill lands, especially, rains sweep immense numbers of infested squares to the lower parts of the fields. Cotton squares are remarkably impervious to water, and weevils may develop in them after decay is far advanced. These squares may be carried many miles from their source and deposited under favorable conditions for the emergence of the weevils.

ARTIFICIAL DISSEMINATION.

While the natural dispersion of the boll weevil is by far the most important means by which new territory becomes invaded, there are certain artificial means of dissemination which are of some importance. The more noteworthy of these are connected with the handling of the cottonseed and cottonseed products. Many weevils are carried to the gins with the cotton. From the gins dissemination may take place in several ways. The weevils may be carried back to the farms in cottonseed to be used for planting, or they may be shipped by rail to the oil mills along with the seed. Moreover, weevils are likely to secrete themselves during cool weather in the wrapping of cotton bales. In this manner transportation along with the lint is possible, although experience has shown that the danger from this source is inconsiderable. When the cottonseed arrives at the oil mill there is chance of infestation from flight into neighboring cotton fields. The greater damage, however, is in the shipment of weevils beyond the oil mills in the cars which have been used for the purpose of carrying the seed to those establishments.

Among the means of minor importance may be mentioned the incidental carriage by vehicles, including railroad coaches, by the movement of plantation laborers, and by intentional carriage for the purpose of experimentation or exhibition. The possibility of spread by these various means will be discussed in the following paragraphs:

MOVEMENT OF SEED COTTON.

Many immature or teneral weevils are carried to the gins with the seed cotton. Adults are frequently found crawling over the wagons filled with unginned cotton. The devices for removing foreign matter from cotton in the process of ginning are numerous and effective. Many of the weevils are removed or destroyed, but adults, as well as larvæ and pupæ, are likely to pass through the gin with the seed. This has been determined by the Bureau of Entomology by running gins experimentally.[1] Many of the weevils, consequently, are carried into the seedhouse along with the cottonseed. Moreover, many of those that are removed by the cleaning devices are not injured. They pass along with the motes into a barrel or box, which is generally uncovered, and from there they frequently fly about and find their way into the cottonseed, or they may secrete themselves in the bagging of the bales standing in the gin yard. Furthermore, many of the adult weevils are not taken into the gin house at all. Being on the cotton in the wagon, they are disturbed by the process of unloading and may fly to any portion of the plant. Consequently, cottonseed in storage at the gin may become infested by any one of the

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[1] For a full account of these experiments see Farmers' Bulletin 209.

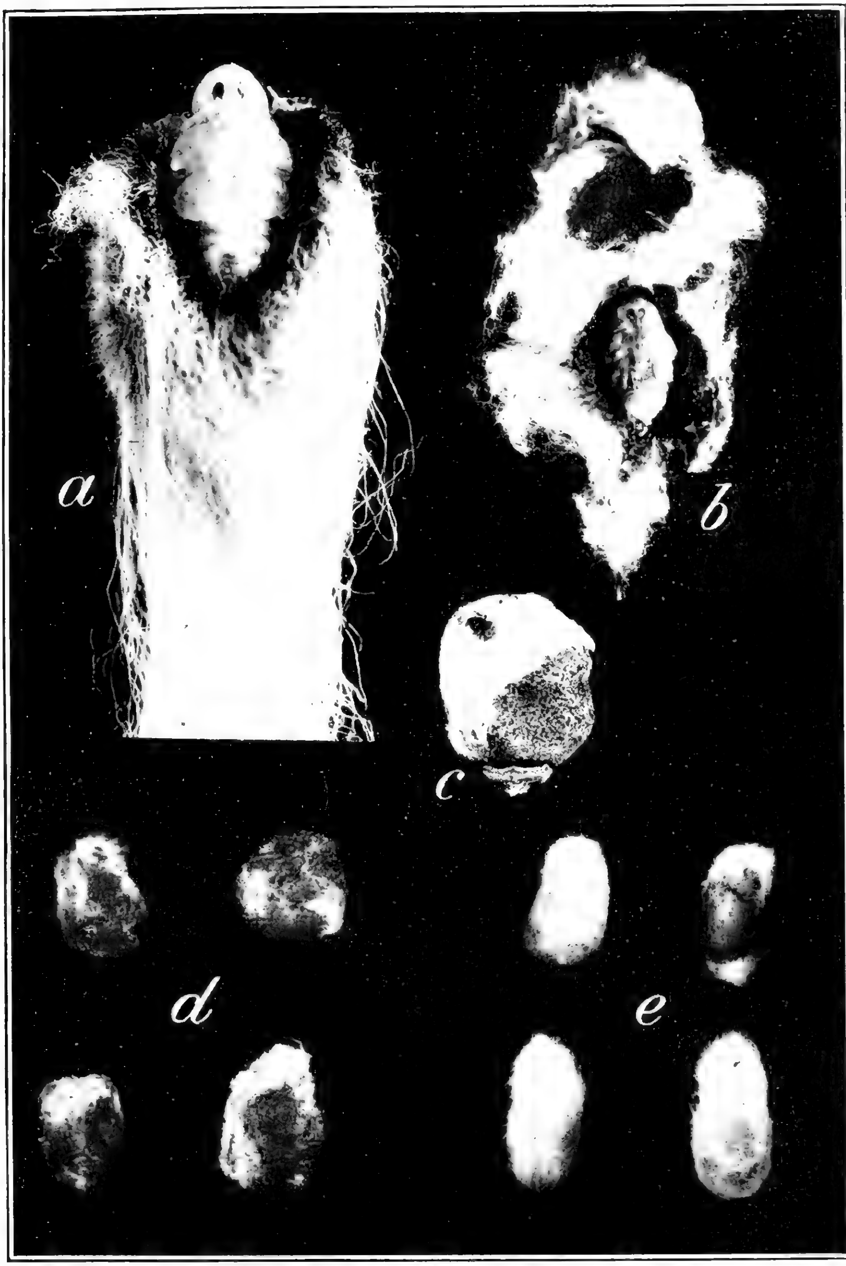
following means: (1) By passage of weevils through the gins along with the seed; (2) by the weevils finding their way into the seed house from the receptacle containing the discharge from the cleaner feeder; and (3) by flight from the wagons during the process of unloading. Thus, gins may serve as important agencies in the dissemination of the boll weevil by the shipment of the seed or possibly of baled cotton. That the danger in baled cotton is slight is shown by the fact that no colonies have been found to have become established in spite of extensive shipments out of the infested territory which have been made for several years.

In many localities the unginned cotton is carried for a distance of 20 miles or more to the gins. It frequently happens that this carriage is into uninfested territory. Under such conditions it is evident that an important form of artificial dissemination of the weevil occurs. Two examples will be given of the possibility of the dissemination of the weevil by such means. In October, 1904, a shipload of unginned cotton was carried across Lake Calcasieu, La., from Grand Lake and Lakeside to Cameron. The latter place was free of the weevil and isolated by extensive stretches of swamp lands. Shortly after the shipment reached Cameron, however, an infestation was found in the gin yard. It was in all probability due to the carriage of the cotton from the opposite side of the lake. In the other case a shipment of unginned cotton was made from Yucatan, Mexico, to Mobile, Ala., in 1909. The Mexican locality was infested by the boll weevil, while the region about Mobile was free of the insect. No infestation resulted in this case for the reason that the shipment from Mexico was accidentally delayed in transit and did not reach Mobile until all of the weevils had died. If the shipment had been made according to the regular schedule there is little doubt that an infestation in the vicinity of Mobile would have resulted.

MOVEMENT OF COTTONSEED.

In ginning districts on the edge of the infested territory the customers are composed of those whose fields are infested and those whose fields are not infested. The inevitable result is that weevils are constantly brought into the gin yards by the farmers, and in the subsequent movements of the cotton are spread broadcast. Some of them may alight upon the wagons filled with the seed to be returned to the farm and consequently may be frequently carried to uninfested farms. The most striking illustration of infestation by this means was found in Shelby County, Tex., in 1904. An establishment on the border line ginned for farmers in a radius of 10 miles or more. Some of the customers had the weevil. The ginner himself had a few weevils on his place, but had raised an exceptionally large crop of big-boll cotton, for the seed of which quite a demand arose. An investigation of the farms in this district showed that all the customers who had purchased this seed had infestations near their seed house. Very few of the other farms in the vicinity were found to be infested.

Cottonseed is frequently shipped considerable distances from the gins to the oil mills. As has been shown there are abundant chances that the seed may become infested at a gin within the infested territory. (See Plate IX.) At the oil mills the cars are unloaded and



RELATION OF BOLL-WEEVIL CELLS TO SEED.

a, Boll-weevil pupa found in cotton seed; *b*, boll-weevil pupa in cell of lint from boll; *c*, weevil cell in dwarfed cotton boll containing live pupa taken among seed; *d*, weevil cells in bolls; *e*, cotton seeds. (Original.)

passed on to the railroads for other uses, frequently without being swept out at the mills. It is common in the lumber country for cars to pass from oil mills to lumber mills. Such cars are often found containing several pounds of seed in the corners. The lumber men sweep out this waste before loading their cars. In case cotton grows near the mill the danger is quite apparent.

An interesting example of the shipment of the weevil in cottonseed came to notice in Mexico a few years ago.[1] On January 5, 1903, it was discovered that Texas-grown cottonseed was being imported into the southeastern part of the Laguna district in Mexico.[2] Examination of this seed, made by Prof. L. de la Barreda, revealed the fact that six lots had been received from infested points in Texas and that each of these lots was at that time infested with live boll weevils. The results of an examination of samples from three consignments are given in Table XXXII.

TABLE XXXII.—*Result of examination of infested cottonseed shipped to Mexico.*

Number of sacks of seed examined.	Boll weevils found.	Alive.	Dead.
8	27	2	25
4	11	2	9
2	57	10	47
14	95	14	81

The results of these careful examinations show very clearly the possibility of transporting live weevils in shipments of cottonseed. Unless the oil mill is within the infested territory and ships hulls to points outside there can be very little danger from this product. In fact, it is hardly possible that weevils are ever spread by means of cottonseed hulls.

BALED COTTON.

One of the writers has found live weevils in bagging about bales consigned to Liverpool on the wharves at New Orleans. However, as has been pointed out, experience has shown that the danger from this source is very slight.

PASSING VEHICLES.

Carriages, wagons, and railroad trains, in passing fields where the weevils are numerous, may carry them great distances, although few specific observations have been made on this matter.

MOVEMENT OF FARM HANDS.

Many laborers frequently pass from infested territory to uninfested territory. Their practice is to use cottonseed for packing breakable household articles. If the movement takes place late in the season

[1] The remainder of this and the next paragraph are from Bull. 51, p. 125.
[2] Boletin de la Comision de la Parasitologia Agricola, vol. 2, pt. 2, pp. 45–58.

this cottonseed or sacks used in infested fields may easily be the means of spreading the insect. It is thought probable that a sporadic infestation at Jackson, Miss., in 1908, originated by such means from the heavily infested district around Fayette, Miss.

UNEXPLAINED SPORADIC OCCURRENCES.

Infestations at Wichita Falls and Paris, Tex., in 1904, far removed from other infestations, can not be explained. A reported infestation in 1909 at Temple, Okla., is also of the same nature.

INTENTIONAL TRANSPORTATION OF THE WEEVIL.

On several occasions it has been found that the boll weevil has been carried into uninfested territory purposely. In some cases the intention has been merely to exhibit live specimens and in others to test supposed remedies. Whatever the purpose of these introductions may be, the practice must be strongly condemned. It is very likely to result in the infestation of localities many years in advance of the time the weevil would reach them by natural means. The result would be a great and unnecessary loss, not only to cotton planters, but to merchants and others dependent upon the cotton trade. In this connection attention is directed to the fact that a Federal statute prohibits the interstate shipment of the boll weevil, as well as other important insect pests, and prescribes heavy penalties.[1] This act is reprinted in part, under the heading "Legal Restrictions," on a subsequent page.

In addition to the Federal legislation on this subject practically all of the States in the cotton belt have statutes which prohibit the importation or having in possession of live boll weevils for any purpose whatever. (See the section at the end of this bulletin.)

HIBERNATION.[2]

There are many popular misconceptions regarding the manner in which the boll weevil passes the winter. For this reason we take the opportunity to point out some general considerations about hibernation.

Many forms of animal life suspend activity during the winter. This is the case with the boll weevil and many other insects, as well as with certain other animals. During this period of inactivity the animals which hibernate derive sufficient nourishment from a supply stored within the body to maintain life. They obtain no other form of food. In fact, the hibernation period coincides more or less with the periods in which the native food supply is absent. The temperatures which kill the cotton plant force the boll weevil into winter quarters, where it remains with suspended animation until spring. Almost coincident with the first sprouting of cotton we find the weevils leaving their winter quarters and moving about in the fields.

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[1] An act to prohibit importation or interstate transportation of insect pests, etc. (Act of Mar. 3, 1905, ch. 1501, 33 Stat. L., 1269.)

[2] Two excellent publications on the hibernation of the boll weevil have been issued. These are: "The Hibernation of the Boll Weevil in Central Louisiana," by Wilmon Newell and M. S. Dougherty (Cir. 31, La. Crop Pest Commission), and "Hibernation of the Mexican Cotton-Boll Weevil," by W. E. Hinds and W. W. Yothers (Bul. 77, Bur. Ent., U. S. Dept. Agr.).

The long absence of the weevils from the cotton fields has led superficial observers to believe that the weevils pass the egg stage in the cotton seed. Such persons point out the fact that the weevils are found in seed houses and appear most abundantly in the fields near these buildings, and also that they have found insect larvæ in the seed. As a matter of fact, the insects found in the cotton seed are not boll weevils, but other species which feed upon dried seeds and similar vegetable matter. The appearance of the early weevils in the vicinity of seed houses is due entirely to the fact that the protection offered there attracts many in the fall. Careful observations throughout the winter have shown that the boll weevil remains inactive except for very slight movements during very warm periods and that it does not breed in or feed upon cotton seed.

As explained in another portion of the bulletin, the hibernation period is defined by the continuance of mean temperatures within what we define as the zone of hibernation. This zone has as its upper limit the mean temperature above which, if continued for any considerable period, the life activities must be resumed, and has for its lower limit the absolute temperature below which no weevil can live for even a short time. For all practical purposes the hibernation zone lies between 56° and 12° F.

METHODS OF STUDY OF HIBERNATION.

In studying several features of the hibernation of the boll weevil the practice has been to utilize large cages covered with wire screen which were placed in the cotton fields. (See Pl. X, *b*.) No cotton was grown in these cages, but at different dates in the fall large numbers of weevils collected in the adjoining cotton were placed in the cages. It has been considered that the rate of survival of weevils in these cages installed chronologically is an index to the number of weevils that actually survive under natural conditions. It has thus been considered that with 1,000 weevils in a cage installed October 1, which showed a survival of 10 per cent, and a cage containing 1,000 weevils installed on September 15, which showed a survival of 5 per cent, twice as many weevils would have survived the destruction of the plants on October 1 as on September 15. Although there is no doubt that this method gives a fairly accurate index, there is one objection that can be made to it. This objection is that the number of weevils leaving the field to go into hibernation as the season progresses, the number dying in the fields, and the number maturing there are not taken into consideration as the calculations have been made. On September 15 none of the weevils in the field would have entered into hibernation. By the 1st of October, however, a certain number would have left the field, and such weevils would not be represented in the collections made for the cage installed on October 1. It is not known whether the weevils which remain in the fields late are more or less hardy than those which leave early to find hibernating quarters. The indications, however, are that the stronger and more active weevils—that is, those more likely to survive the winter—are the ones which do not go into hibernation at an early date. Nevertheless the number that may have gone into hibernation between the dates of the installation of the various cages, the number that died from natural causes, and the number that matured in the fields during that

time must be considered. As a matter of fact, the total number of weevils in a locality on October 1 would be the number present in the cotton fields on September 15, less the total number dying between September 15 and October 1, and less the number leaving the field to enter into hibernation during that period, plus those that matured during the same time. It is likely that the number of weevils maturing is generally sufficient to offset the number that die from natural causes. This leaves only the weevils which escape collection by entering into hibernation to be considered. As there is no way in which this number can be determined, the method we have followed, which ignores them altogether, is the closest approximation we can make to a determination of the actual number of weevils which succeed in passing the winter after the destruction of the food plants in the fall.

It is to be noted that the possible error in the interpretation of the results of hibernation experiments becomes greater in the case of the cages installed late in the season. As the season advances more and more of the weevils leave the fields and thus pass out of consideration in connection with the number collected and placed in the cages.

The hibernation experiments conducted have dealt with 181,932 weevils utilized in seven different seasons in seven localities throughout the infested territory.

ENTRANCE INTO HIBERNATION.

SOURCES OF WEEVILS ENTERING HIBERNATION.[1]

Following the maturity of a considerable portion of the crop of bolls, and usually in connection with the occurrence of a heavy rainfall, a renewed growth of the plant commonly produces an abundance of squares. It is this late top growth of the plant, which serves no good purpose so far as further production of cotton is concerned, that is primarily responsible in most fields for the needlessly large number of weevils produced between the time of maturity of the crop and the usual time of destruction of the plants by frost. A large proportion of the weevils which become adults before September 1 may be expected to die, either as cold weather comes on or during the early part of the winter season. There is no particular hibernation brood, but representatives of all generations may survive and enter hibernation, as has been shown by figure 14 in the discussion of the life cycle.

STAGES ENTERING HIBERNATION.[2]

The reproductive activity of the weevil continues steadily until the plants are destroyed by frost, but it gradually decreases coincidently with the gradual decrease in temperature. All stages from the egg to the adult may be found in both squares and bolls, even after frosts have occurred. The immature stages in squares are not immediately killed unless the freeze is exceptionally severe, and in some localities many of these survive to reach maturity and to emerge during the following spring. Usually, however, only those which are nearly adult at the time frost occurs may be expected to

[1] The matter in this section is mainly extracted from Bull. 77, Bureau of Entomology, pp. 12, 13.
[2] The matter in this section is largely extracted from Bull. 77, pp. 13, 14.

emerge. These might emerge upon warm days following the colder weather, but in the absence of a fresh food supply would soon die. In the fall of 1903 Prof. E. D. Sanderson, in an examination of 700 squares at the middle of November, found 79 eggs, which means that 11 per cent of the squares contained eggs. In an examination of 1,600 squares he states that 366 larvæ were found, showing that about 23 per cent of the squares contained larvæ at the time of entrance into hibernation.[1] Some stages may survive in squares for a short time after the freeze, but there are few records of weevils entering hibernation as immature stages in squares and surviving to emerge therefrom in the spring. These stages are therefore unimportant from an economic point of view.

With immature stages entering hibernation in bolls, the case is quite different from that in squares. Very large numbers of weevils enter upon the period of hibernation as immature stages and during many seasons, especially in the southern part of the State, a large percentage of these complete their development, and many survive until time for their emergence in the spring. Immature stages in bolls have been found alive at Victoria, Tex., as late as February 17.

TIME OF ENTERING HIBERNATION.

Hibernation begins when the temperature reaches a point between 60° and 56° F. The exact point will be higher with a high percentage of humidity and lower with a low percentage of humidity.

According to the observations of Messrs. Newell and Dougherty,[2] at Mansura, La., in 1908, entrance into hibernation began on October 28. The mean temperature for 10 days preceding that date was 63.7° F., but the minimum dropped from 46° to 31° F. on the day the weevils began to enter into hibernation.

The action of the weevils in securing shelter from approaching cold is instinctive rather than intelligent. It is probably true that they have no such sense of sight as we commonly understand from the use of that word and that their selection of shelter is not at all guided by that sense. We mean by this that a weevil on a cotton plant can not see at any distance shelter which might be attractive to it and thereupon fly from the plant to the shelter. Cold nights with a temperature between 40° and 50° F., succeeded by warm still days, such as occur commonly in the fall, seem to stimulate the weevils to an unusual activity both in flight and in crawling. It seems possible that they have an instinctive knowledge of the approach of temperature conditions from which they must secure shelter, but it is also true that many weevils remain active upon plants for some time after the plants have been destroyed by frost and frequently until several weeks after other individuals have entered hibernation. In speaking of entering hibernation, therefore, we mean the entrance of the weevils upon a period of comparative if not complete inactivity. Their action in securing shelter is gradual and governed primarily by the degree of protection from the cold which they may receive. If early in the season a weevil accidentally finds shelter which gives it exceptional protection from the cold it will likewise be exceptionally protected from heat and therefore less likely than are other less

[1] Bull. 63, Bureau of Entomology, U. S. Dept. of Agriculture.
[2] Cir. 31, Lousiana Crop Pest Commission, p. 170.

fortunate individuals to resume its activity upon warm days. If at first the shelter which weevils find is only slight they will be easily influenced by succeeding warmth, and in another period of activity will be likely to find better protection. Their flight upon warm days undoubtedly leaves large numbers of them outside of the cotton fields, where they are more likely to find favorable shelter than within the fields themselves.

From this explanation it will be understood that it is rarely possible to indicate by a single date the time when weevils enter hibernation. It may be better expressed as a period within the limits of which a large majority, though possibly not all, weevils may seek shelter. Naturally this time varies according to the seasonal temperature conditions, so that in a certain locality it may occur several weeks earlier in one season than in another. It is also evident that differences in temperature conditions due to latitude or altitude will cause a similar variation in the time when weevils enter hibernation.[1]

In Table XXXIII are shown the times of the year in which the weevils entered hibernation in the experiments of 1903 to 1906, together with the temperature conditions prevailing. The table shows the relationships between humidity and temperature and the length of the period of entrance into hibernation. In short, it may be stated that the lower the mean temperature the shorter the period of entrance. Sufficient information is not at hand to show positively the influence of humidity, but it is evident that there is a decided influence.

TABLE XXXIII.—*Period of entrance of the boll weevil into hibernation and meteorological conditions.*

Year.	Locality.	Period.		Mean temperature.	Mean humidity.
		Limits.	Days.		
				°*F.*	*Per cent.*
1905	Dallas, Tex.	Nov. 29–Dec. 8	10	40.5	64.8
1903	College Station, Tex.	Nov. 15–27	13	49.5	....
1903	Victoria, Tex.	Nov. 15–30	16	53.0	....
1905	.....do	Nov. 30–Dec. 18	19	50.0	....
1904	Corsicana, Tex.	Nov. 10–Dec. 5	26	55.0	....
1906	Dallas, Tex.	Nov. 12–Dec. 8	27	53.0	73.1
1904	Victoria, Tex.	Nov. 11–Dec. 8	28	57.5	79.3
1906	.....do	Nov. 9–Dec. 21	43	60.4	....

Weevils can not be forced to hibernate when conditions do not normally induce hibernation. If kept without food, they will starve. The real bearing of this statement will be brought out later in connection with the summaries of the survival in its relation to the time of beginning hibernation. (See Table XLVI.)

NUMBER OF ADULT WEEVILS ENTERING HIBERNATION.

Of course the number of adult weevils entering hibernation is a variable quantity, owing to the differences in the percentage of infestation in various regions and seasons. Examinations in heavily infested regions have shown averages as high as 58,000 adult weevils

[1] This and the preceding paragraph are remodeled from Bull. No. 77, Bureau of Entomology.

per acre in the middle of November. In this connection it is interesting to note the progress of entrance into hibernation as shown by Table XXXIV, based on investigations made at Dallas in fields with an average of 8,300 plants per acre.

TABLE XXXIV.—*Number of boll weevils per acre upon stalks at different dates at Dallas, Tex.*[1]

Date.	Plants examined.	Living weevils found.	Living weevils per acre.
1906.			
Oct. 12	110	122	9,205
Oct. 31 to Nov. 3	84	190	18,774
Nov. 10	60	106	14,663
Nov. 20	35	29	6,877
Nov. 22	35	27	6,403
Dec. 1	36	10	2,306
Dec. 18	35	5	1,186
1907.			
Jan. 21	35	3	711

[1] From Bull. 77, Bureau of Entomology, p. 18.

In connection with this subject we include also Table XXXV for the same period, showing the occurrence of the weevils under shelter on the ground in the cotton fields.

TABLE XXXV.—*Number of weevils under rubbish on ground at Dallas, Tex.*[2]

Field.	Date examined.	Portion of acre examined.	Weevils found—Alive.	Weevils found—Dead.	Total per acre.	Percentage alive.	Remarks.
	1906.						
A	Nov. 15	22 plants.	4	0	1,450	100.0	In cracks of ground around bases of plants.
A	...do...	1/264	4	0	1,056	100.0	Under rubbish on ground.
A	Nov. 22	1/347	8	0	2,776	100.0	Do.
A	Dec. 18	1/264	5	14	5,016	26.3	Do.
	1907.						
B	Jan. 11	10/8384	5	2	5,870	71.4	Northeast corner of field.
C	Jan. 29	10/6236	1	1	1,247	50.0	Middle of field.
C	...do...	10/8384	2	2	3,354	50.0	Near southwestern edge.

[2] This table and the following paragraph are taken from Bull. 77, Bureau of Entomology, p. 20.

The sum total of weevils found both on plants and on the ground on November 22 shows an average of slightly more than 9,000 weevils per acre, all of which were alive. On December 18 the number that could be accounted for was between 6,000 and 7,000 per acre on the same ground which had been previously examined. On the former date more than two-thirds of the weevils were still upon the plants. On the latter date nearly five-sixths of them were on the ground, and among those on the ground only 26 per cent were living. These figures show that between November 22 and December 18 a very large mortality had occurred among weevils which had entered hibernation, and especially among those which had sought shelter under rubbish upon the surface of the black-waxy soil of field A.

SHELTER DURING HIBERNATION.

Boll weevils in seeking shelter from the cold will enter all kinds of places which might afford shelter. The following statements are quoted from Prof. E. D. Sanderson: [1]

> The observations by Prof. Conradi at College Station, Tex., in the early winter of 1903, probably indicate some of the normal places for hibernation—that is, under dead leaves, in old cotton brush, and under loose bark. In the hibernation cages, where the weevils were furnished an abundance of rubbish, it was found that many of them which were hibernating successfully had crawled into the cavities made by borers in dead wood and in similar positions where they were well protected. It has been often noticed that in a wooded country the weevils appear first in spring along the borders of fields next to the woods and gradually work inward from the edges, so that it seems probable that in a wooded country most of them hibernate in woodland. Around outbuildings and barns also are found favorable places, as there is always more or less rubbish and protection in such situations. In 1903 more than five times as many weevils were found in a piece of cotton near the college barn, where cotton had been grown the previous year, than were found in any other locality in that neighborhood. It is also noticeable that weevils are always more numerous near gins than at a distance from them.
>
> It is noticeable that weevils are much more abundant where cotton is planted in fields where sorghum stubble has been allowed to remain all winter adjoining a last year's cotton field.
>
> Professor Mally has given the observations of Mr. Teltschick upon finding weevils hibernating in the crevices of the soil around the cotton stalks and roots, at a depth of 3 inches. On March 7, 1901, a raw, windy day, upon 35 stalks, he found 7 live and 2 dead weevils from 1 to 3 inches below the surface. In September, 1902, he stated that he had again found weevils in a similar situation during the previous spring, but not as many of them as in 1901. Mr. Teltschick recently writes as follows:
>
> "I found but few weevils in crevices around stalks during the last two winters, partly because there were no crevices (frequent rains filling them up as soon as formed) and partly because freezes were severe enough to keep cotton from coming out during any part of the last two winters; whereas in 1900 we had neither rain enough to fill up crevices nor frost enough to keep cotton from budding out at intervals at the base of the stalk, which latter fact accounts, no doubt, for the relatively large number of weevils found within the crevices."

Where the cotton stalks are allowed to stand throughout the winter they furnish the weevils both the means of subsistence late in the fall and an abundance of favorable hibernation places throughout the field. The prospects of successful hibernation are thereby multiplied many times, and, furthermore, the weevils are already distributed over the field when they first become active in the spring. The grass and weeds which almost invariably abound along fence lines are exceedingly favorable to the hibernation of many weevils, so that it will be found generally true that the worst line of infestation in the spring proceeds from the outer edges of the field inward. Where cotton and corn are grown in adjacent fields, or where, as is sometimes the case, the two are more or less mixed in the same field, many weevils find favorable shelter in the husks and stalks of the corn. An especially favored place is said by Mr. E. A. Schwarz to be in the longitudinal groove in the stalk and within the shelter of the clasping base of the leaf. Perhaps the most favorable of all hibernating conditions are to be found among the leaves and rubbish abounding in the edges of timber adjoining cotton fields and in Spanish moss. From such sources the weevils are known to come in large numbers in the spring. Sorghum stubble, which collects débris blown about by the wind, is also very favorable for hibernation.

[1] Bull. 63, Bureau of Entomology, U. S. Dept. Agriculture, pp. 18–19.

Fig. a.—Standing dead timber and forest environment favorable for hibernation of weevils. (Original.)

Fig. b.—Litter in forest, suitable for hibernation of weevils. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

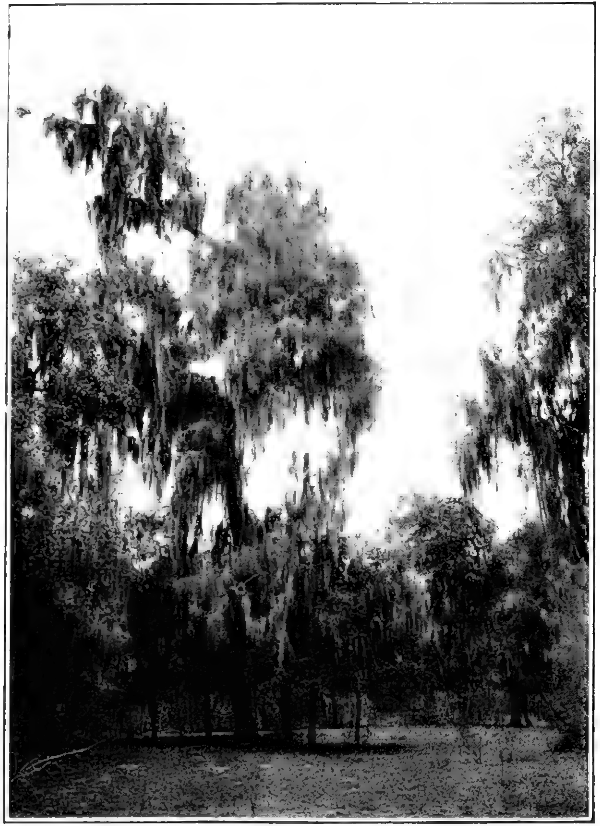


Fig. a.—Spanish moss on trees; very favorable for hibernation of weevils. (Original.)

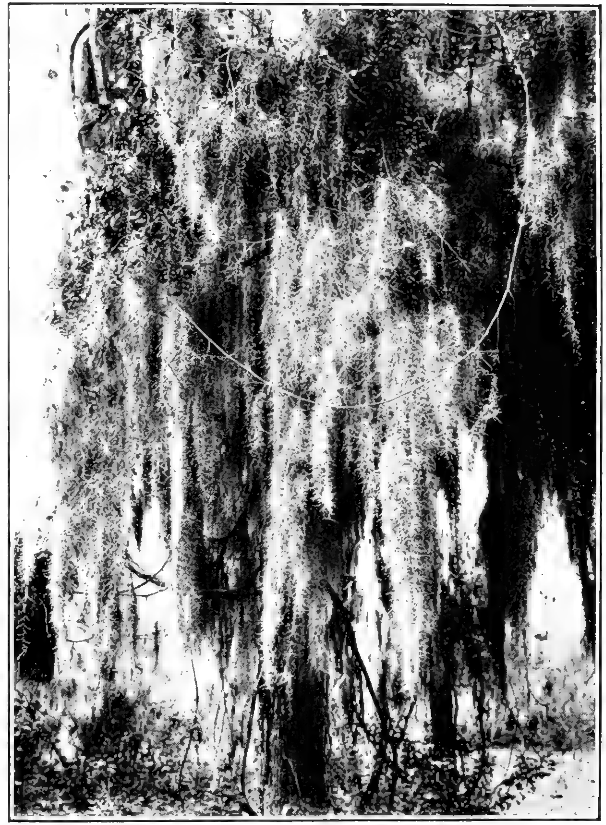


Fig. b.—Density of Spanish moss as a protection to weevils in hibernation. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

Attention has already been called to the fact that many stages enter the period of hibernation in an immature condition in unopened bolls. That adult weevils hibernate entirely within the protection afforded by the bracts and hulls of bolls has been abundantly demonstrated. Messrs. Hinds and Yothers[1] showed, however, that the percentage of live stages in bolls decreased rapidly during the winter, thus proving that the bolls do not furnish perfect hibernation shelter. Their results may be summarized as follows:

TABLE XXXVI.—*Seasonal decrease of live stages of the boll weevil in bolls; percentage of bolls containing live stages.*

December	36.00
January	1.15
February	0.29
March	0.00

As would be expected, it was found that there was a greater percentage of survival in bolls in southern localities.

During an ordinary season it can not be doubted that a large majority of the weevils which survive find some other shelter than the bolls hanging upon the plants. It is not, however, as easy a matter to find weevils in rubbish scattered upon the ground as in bolls. It is necessary to collect the rubbish very carefully and sift it over cloth or paper to separate the weevils from the trash. In this way it has been found that weevils hibernate extensively in the leaf and grass rubbish distributed throughout the field. Naturally, the cleaner the field in the fall the smaller will be their chances of finding favorable shelter during the winter.[2] (Pl. XII, *b*.)

Standing trees are a common sight in cotton fields, and while the records of weevils found hibernating under bark are but few, they are sufficient to indicate that these trees may be rather important factors where they occur in considerable numbers. (Pl. XII, *a*.)

Where the Spanish moss (*Tillandsia usneoides*) occurs, as in the bottom lands in the coast section of Texas and in the southern portions of the Gulf States generally, weevils find exceptionally favorable shelter. Many examinations of large quantities of moss have been made to ascertain the importance of this form of shelter. The maximum number of weevils per ton of moss is recorded by Messrs. Newell and Dougherty (1909) as 3,158 in moss collected from an elm tree located in a swamp at Mansura, La., December 23, 1908. The moss was at a height of 15 feet. The tree was one-fourth of a mile from the nearest cotton field. On January 9, 1910, Mr. C. E. Hood found at Mansura 924 boll weevils and 2,156 boll-weevil parasites per ton of moss collected at from 1 to 8 feet above the ground. The weevils seem to prefer the festoons of green-hanging moss to the dead masses. (See Pls. XI, XIII.)

Cornfields adjoining cotton, or cornstalks scattered throughout cotton fields may shelter many weevils. This was first noticed by Mr. E. A. Schwarz at Victoria, Tex., in the winter of 1901–2, and has since been corroborated by a number of observers. Several examinations have been made of haystacks in the vicinity of cotton.

[1] Bull. 77, Bureau of Entomology.
[2] This paragraph and the remainder of the discussion in the present section is modified from Bull. 77, Bureau of Entomology, pp. 30–33, 41, 42.

This is a task quite comparable with that of seeking for the proverbial needle, and it is not surprising that the results have been very meager. The fact, however, that traces of weevils have been found in these examinations indicates that weevils may find shelter under such conditions.

Farmyards, seed houses, barns, ginneries, and oil mills also afford favorable shelter for weevils. Especially in ginneries and seed houses the weevils become concentrated with the cotton or seed and frequently may be found in large numbers within or around these buildings. In connection with this subject the reader is referred to a fuller discussion of the significance of ginneries and oil mills in the distribution of weevils and of the methods recommended for controlling them.[1]

In order to have a basis of comparison of the various kinds of shelter, many cage experiments have been conducted. In Table XXXVII will be found a comparison of the survival in the cages at Keatchie, La., for weevils installed November 23 and 29.

TABLE XXXVII.—*Favorable conditions for hibernation determined by rank in percentage of weevils surviving at Keatchie, La., in 1905–6.*[1]

Nature of shelter.	Weevils put in.	Weevils survived.	
		Number.	Per cent.
Ordinary field stalks, grass, etc	2,000	93	4.65
Brush, leaves, stumps, logs; stalks standing	2,500	99	3.56
Same as above, but stalks removed	3,300	70	2.12
Cotton seed, piled but uncovered; stalks standing	2,000	30	1.50
Absolutely bare ground	2,000	30	1.50
Cotton seed piled and covered; stalks left standing	2,000	23	1.15

[1] From Bull. 77, Bureau of Entomology, p. 42.

It is evident from these observations that ordinary field conditions where stalks are allowed to stand together with the grass and leaves littered over the ground are as favorable as any other for successful hibernation. One fact should be emphasized in regard to classes of shelter which have been mentioned as occurring within cotton fields, i. e., that it is possible, as a rule, to destroy or remove practically all of them. Undoubtedly the burning of cotton stalks, weeds, grass, and other rubbish is the easiest and most effective method of destruction where it can be practiced. Next to this in importance would be the destruction of the stalks by a stalk chopper and plowing under all the rubbish. In the latter case it must be stated that many weevils which, under dry conditions, are buried not more than 2 inches will be able to escape through the soil and may then find shelter near, if not within, the field.

[1] Farmers' Bull. 209, U. S. Dept. of Agriculture, "Controlling the Cotton Boll Weevil in Cotton Seed and at Ginneries."

ACTIVITY DURING THE HIBERNATION PERIOD.

It is natural to expect that during warm periods of winter the temperature will rise to a point which forces the weevils into activity. Of course, the weevils under the lightest shelter are the ones which first become active. It is these warm periods which cause the intermittent development of the immature stages in dry bolls left in the fields. In some winters the hibernation is incomplete throughout the cotton belt, and in the extreme South it is probably so almost every winter. This same temperature condition is responsible for the growth of sprout cotton, which affords food in the warm periods. Observations were made in January, 1907, on weevils feeding on sprout cotton at Victoria, Tex., at a mean temperature of 67° F.

DURATION OF HIBERNATION PERIOD.

AVERAGE LENGTH OF HIBERNATION PERIOD.

Many factors must be considered in arriving at the average length of the hibernation period. The time of entrance, condition of the weevils on entering, temperature and humidity before and during hibernation, and nature of shelter, all have a decided effect upon the duration of hibernation. In a series of condensed summaries we have attempted to show how some of these factors act.

In Table XXXVIII is to be found a general summary of the nine large experiments conducted, with the extreme variations in each series. From this table it appears that in the years 1906 to 1911 the hibernation period has ranged between 62 and 255 days, and that in 1909 the range fell short only 1 day of this maximum range. It also appears that the average duration in Texas is 26 days shorter than in Louisiana. The period of emergence extends from February 15 to July 1.

TABLE XXXVIII.—*Extremes of variation in duration of hibernation by the boll weevil.*

Place.	Total number weevils emerged.	Total number weevil days.	Minimum period.	Maximum period.	Minimum average.	Maximum average.	Average of averages.	Earliest emergence.	Latest emergence.
			Days.	*Days.*	*Days.*	*Days.*	*Days.*		
Keatchie, La., 1906	731	114,192	108	222	136	178	156	March 22	June 28.
Mansura, La., 1909	3,260	516,067	62	254	94	199	156	February 21.	June 29.
Mansura, La., 1910	1,038	170,212	86	232	114	217	164	February 15.	June 15.
Tallulah, La., 1910	317	58,245	103	237	126	224	183	February 15.	June 27.
Tallulah, La., 1911	46	6,587	107	231	118	158	143	February 15.	June 4.
Louisiana average	5,392	865,303	62	254	94	224	160	February 15.	June 29.
Victoria, Tex., 1907	3,028	383,797	92	223	95	146	126	February 28.	June 15.
Calvert, Tex., 1907	1,842	255,831	91	255	100	195	138	March 4	July 1.
Dallas, Tex., 1907	3,462	481,271	85	233	98	168	138	March 1	June 19.
Dallas, Tex., 1908	118	17,839	113	217	121	170	151	March 2	June 16.
Texas average	8,450	1,138,738	91	255	98	195	134	February 28.	July 1.
Grand total	13,842	2,004,041	62	255	94	224	144	February 15.	July 1.

TABLE XXXIX.—*Average length of hibernation period of the boll weevil as related to date of installation.*

Place.	Time of installation, Sept. 16–30.		Time of installation, Oct. 1–15.		Time of installation, Oct. 16–31.		Time of installation, Nov. 1–15.		Time of installation, Nov. 16–30.		Time of installation, Dec. 1–15.		Time of installation, Dec. 16–31.		Average hiber-nation.
	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	Length of hiber-nation.	Emerged.	
	Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*
Keatchie, La., 1906									158	May 1	146	Mar. 1			
Mansura, La., 1909	183	Mar. 31	170	Mar. 27	185	Apr. 30	157	Apr. 11	143	Apr. 15	124	Apr. 13	94	Mar. 26	
Mansura, La., 1910	217	May 3	180	Apr. 8	165	Apr. 7	162	Apr. 22	159	Apr. 26	146	May 5			
Tallulah, La., 1910	224	May 5	219	May 17	173	Apr. 15	162	Apr. 16	145	Apr. 20		(1)			
Tallulah, La., 1911			156	Mar. 20	125	Mar. 5		(1)		(1)		(1)			
Louisiana weighted average	185	Apr. 3	190	Apr. 16	183	Apr. 24	158	Apr. 15	151	Apr. 23	129	Apr. 16	94	Mar. 26	160
Victoria, Tex., 1907					139	Mar. 14	132	Mar. 22	113	Mar. 19					
Calvert, Tex., 1907			166	Mar. 28	175	Apr. 18	142	Apr. 1	119	Mar. 24	100	Mar. 13			
Dallas, Tex., 1907			168	Mar. 29	149	Mar. 20	135	Mar. 26	125	Mar. 29	98	Mar. 14			
Dallas, Tex., 1908	170	Mar. 17	160	Mar. 21	157	Apr. 1	141	Mar. 30	122	Mar. 20					
Texas weighted average	170	Mar. 17	166	Mar. 21	151	Mar. 23	135	Mar. 23	116	Mar. 9	98	Mar. 14			134
Grand weighted average	176	Mar. 18	180	Apr. 4	168	Apr. 9	139	Mar. 27	130	Apr. 2	126	Apr. 13	94	Mar. 26	144

[1] No emergence.

Knowing that the time of entrance affects the percentage of survival, it is also reasonable to expect an effect upon the duration of the hibernation period. Table XXXIX has been constructed to show the average duration and average date of emergence at each locality for all weevils entering hibernation in each half month during the several seasons of the experiments. It will be noted that the length of the period, with a few minor exceptions, decreases in accordance with the lateness of entrance. It is very strikingly shown that in any given period of entrance the duration in Texas is considerably shorter than in Louisiana. On the other hand, it is impossible to show from this table any progression in the average date of emergence.

The diagram (fig. 22) shows graphically the correspondence between date of installation and period of hibernation and emphasizes the differences between Texas and Louisiana.

RELATION OF SHELTER TO DURATION OF HIBERNATION.

That the nature of the hibernating quarters has a direct bearing upon the duration of the period is to be gathered from the records of Messrs. Newell and Dougherty made at Mansura, La., in 1909, which are abstracted below:

TABLE XL.—*Comparison of length of hibernation of the boll weevil in different shelters at Mansura, La., 1909.*[1]

Date started 1908.	Nature of hibernation quarters.	Location of cage.	Number of weevils contained.	Number of weevils surviving winter.	Average number of days in hibernation.	Average date of emergence.
October 26	Average	In open field	1,294	325	169.1	April 13
Do	do	In swamp	1,142	162	173.3	April 17
Do	Moss	In open field	1,214	409	190.9	May 4
Do	do	In swamp	938	408	199.4	May 13
Total			4,588	1,304		
Average					185.0	April 28

[1] This table and the following statements are extracted from Cir. 31, State Crop Pest Commission of Louisiana.

Consideration of Table XL reveals the interesting fact that weevils hibernating in the cool, shaded situations in timber remained in hibernation an average of about seven days longer than those hibernating in the open field. Weevils which hibernated in moss in the swamp remained in hibernation practically 200 days, and those which passed the winter in moss on trees in the open field remained in hibernation 191 days. In marked contrast to this the weevils that hibernated in a general assortment of materials in the open field remained in hibernation only 169 days, though gathered from the cotton fields at exactly the same date in the fall of 1908. This proves the dangerous nature of the moss, for it really causes the weevils in it to remain in hibernation for nearly a month longer than they would if hibernating in other materials.

Table XL also illustrates the influence of temperature upon the duration of the hibernation period, for there is no doubt that it is the temper-

ature prevailing in the exact spot where the individual weevils are hibernating that determines the date of emergence from hibernation. Piles of grass in the open field are warmed by the sun in February and March, and the weevils emerge from them at that time. The shaded places of the forest or swamp are cool and damp, and they do not reach an

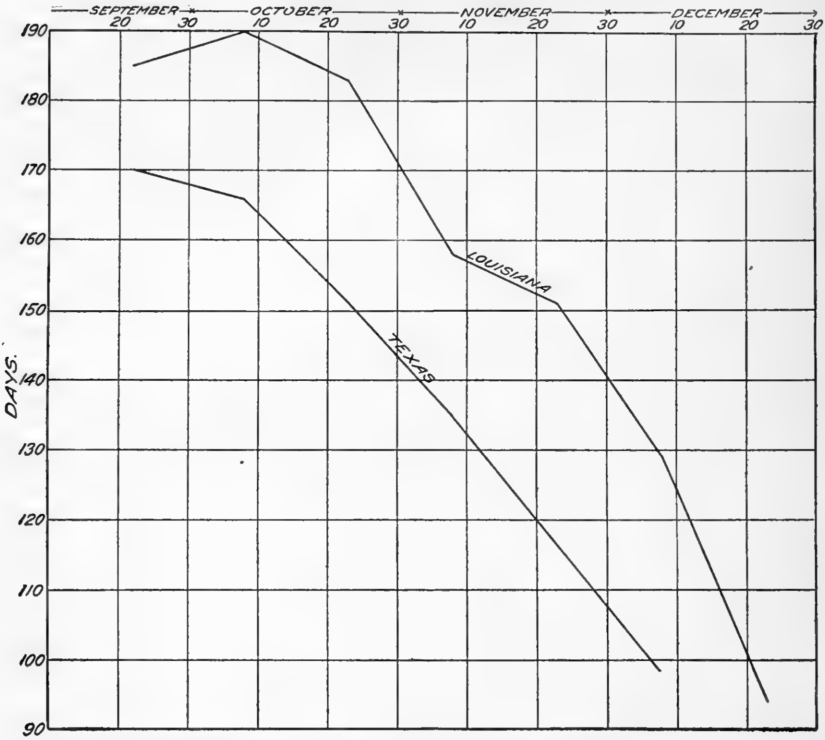


FIG. 22.—Diagram illustrating average length of hibernation period of the boll weevil as related to date of entering hibernation. (Original.)

equivalent temperature until some weeks afterwards, and the weevils consequently emerge later in such places than in the open fields. The bunches of moss are so resistant to heat that even in the hottest days of summer they are very noticeably cooler than the air.

EMERGENCE FROM HIBERNATION.

TIME OF EMERGENCE.

The time of emergence of the boll weevil from hibernation ranges from February 15 to July 1. It is necessary to discuss the conditions which cause this irregularity. A careful study of all the series of experiments to determine the immediate causes for the first decided impulse to emerge has resulted in the following conclusion: That the

time of emergence varies with the total effective temperature and the rainfall. Computing the total effective temperature from January 1 in daily units of mean temperature above the mean of 56° F. (average zero of effective temperature) it is found that approximately 172.6° F. of effective temperature and 5.1 inches of rain are necessary to bring the weevils out of hibernation in comparatively large numbers. If the rainfall is greater than 5.1 inches the necessary effective

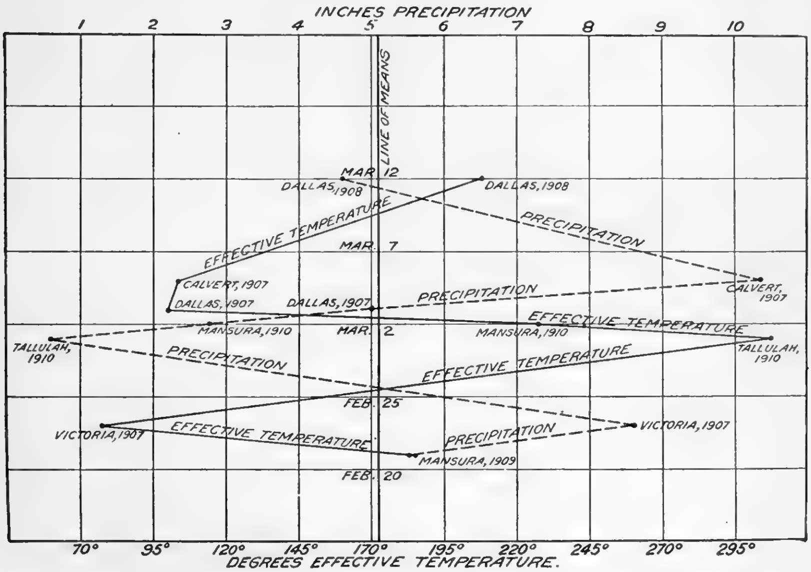


FIG. 23.—Diagram illustrating relations of effective temperature and precipitation to date of beginning emergence of the boll weevil. (Original.)

temperature usually will be less than 172.6° F., and, on the other hand, if the total effective temperature is greater than 172.6° F. the necessary rainfall will usually be less than 5.1 inches. This may be seen by reference to Table XLI and by the diagram (fig. 23). Discrepancies will occur with regard to this formula and will in a large measure be due to the type of shelter or to great irregularities in the climate.

TABLE XLI.—*Relation of effective temperature and precipitation to date of beginning emergence of the boll weevil.*

Place.	Total effective temperature from Jan. 1.	Total precipitation from Jan. 1.	Date of first extensive emergence.
	° *F.*	*Inches.*	
Tallulah, 1910	65	10.5	March 1.
Mansura, 1910	115	7.3	March 2.
Dallas, 1908	160	6.5	March 12.
Dallas, 1907	170	2.2	March 3.
Mansura, 1909	185.5	5.5	February 21.
Victoria, 1907	260	1.3	February 23.
Calvert, 1907	303.7	2.35	March 5.

Figure 23 shows graphically that climate influences the time of beginning emergence. It also has a decided effect upon the subsequent emergence. In Table XLII is shown what effect the daily mean temperature has upon the hibernating weevil.

TABLE XLII.—*The relation of emergence of the boll weevil to increase in temperature at Keatchie, La., and Dallas, Tex., 1906.*[1]

Range of temperatures (° F.).	Keatchie, La.		Dallas, Tex.		Total number of weevils emerged.	Per cent based on grand total emerged.
	Number of weevils emerging.	Per cent of total emergence.	Number of weevils emerging.	Per cent of total emergence.		
43-57	20	2.7	0	0	20	2.5
58-63	52	7.1	2	3.6	54	6.8
64-68	116	16.0	25	45.5	141	17.8
69-73	127	17.5	18	32.7	145	18.5
74-78	309	42.4	10	18.2	319	40.7
79-83	84	11.5	0	0	84	10.7
84-93	20	2.7	0	0	20	2.5
Total	728	100.0	55	100.0	783	100.0

[1] Modified from Bull. 77, Bureau of Entomology, p. 44.

The number of weevils emerging under 57° F. is very small indeed. From that point the emergence increases with the increase in temperature until a majority of the weevils have emerged. Most weevils have been found to leave their winter quarters during a temperature averaging between 64° and 78° F. At Keatchie 75 per cent and at Dallas 96 per cent of the total emergence took place between these limits. At Dallas the largest emergence occurred between temperatures of 64° and 68° F., while at Keatchie the largest emergence occurred between 74° and 78° F. In a preceding paragraph we have shown that higher temperatures are necessary to affect the weevils hibernating in Louisiana, apparently because of the heavier shelter.

RATE OF EMERGENCE.

With a long-continued emergence period it is important to determine whether the rate of emergence is equal at all times or has its periods of retardation and acceleration. Upon charting the percentage of total emergence for each week it was noted that the Texas and Louisiana points differed considerably. On the accompanying diagram (fig. 24) the four Texas series are consolidated to give the average rate, and likewise the four Louisiana series are consolidated, while in Table XLIII the records for each locality are given. It is immediately apparent that the emergence begins much

more abruptly in Texas than in Louisiana. In Texas 25 per cent have emerged by March 12, 50 per cent by March 21, 75 per cent by April 8, and 100 per cent not until June 19. On the other hand, in Louisiana 25 per cent have not emerged until March 30, 50 per cent until April 27, 75 per cent until May 16, while 100 per cent will have emerged only by July 3. Herein lies a powerful argument for early planting. With 50 per cent of the weevils emerging after March 21 in Texas

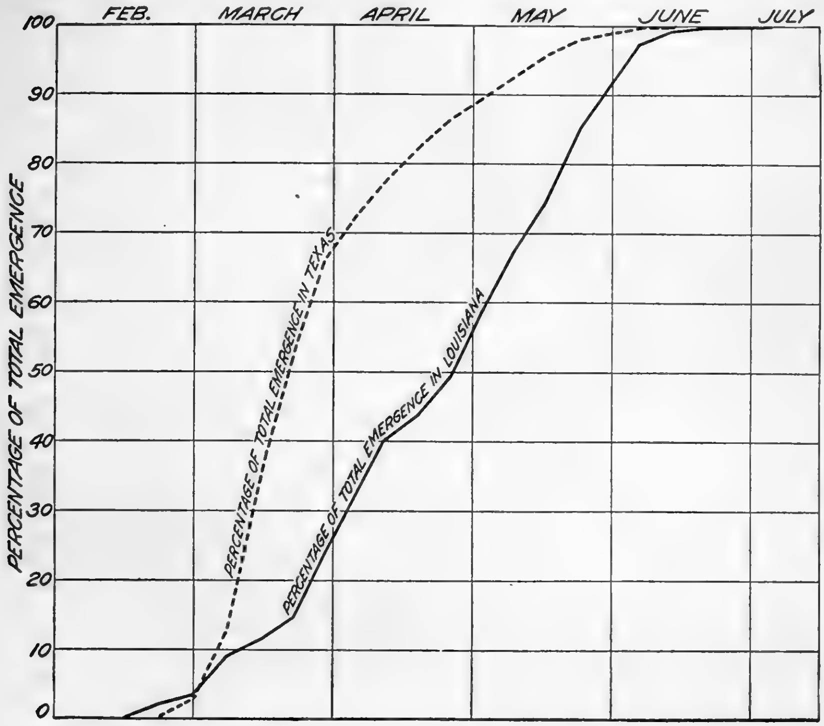


FIG. 24.—Diagram illustrating average rate of emergence of the boll weevil from hibernation in Texas and Louisiana. (Original.)

and 86 per cent emerging after the same date in Louisiana, or with 75 per cent emerging after April 8 in Texas and 64 per cent yet to emerge after the same date in Louisiana, it becomes evident that every day gained in Texas before March 21 or in Louisiana before April 8 is of immense importance in the fight against the weevil. Even later than these dates every day counts a great deal, because it is apparent that the longer planting is deferred the more weevils will be out to attack the cotton when it comes up.

TABLE XLIII.—*Percentage of total emergence of the boll weevil out at given dates.*

Date.	Keatchie, La., 1906.	Tallulah, La., 1910.	Mansura, La., 1910.	Mansura, La., 1909.	Dallas, Tex., 1908.	Calvert, Tex., 1907.	Dallas, Tex., 1907.	Victoria, Tex., 1907.	Tallulah, La., 1911.
February 21	0.00	0.31	1.64	7.20	0.00	0.00	0.00	0.00	36.95
February 28	.00	.31	3.28	10.61	.00	.00	.00	12.01	36.95
March 7	.00	6.62	10.56	19.22	7.27	22.80	24.48	27.92	39.92
March 14	.00	10.09	15.69	19.73	23.63	31.90	36.36	48.23	63.83
March 21	.00	13.56	21.19	23.24	45.45	44.30	57.14	66.24	70.35
March 28	3.93	23.34	38.05	30.95	55.45	57.20	71.72	79.35	72.52
April 4	6.87	35.95	46.53	38.16	63.63	64.20	75.70	84.16	74.69
April 11	24.54	41.95	49.42	43.87	68.18	70.40	81.28	89.58	81.21
April 18	32.11	46.05	52.41	47.78	74.54	77.70	84.46	93.80	87.73
April 25	40.67	48.89	53.86	56.39	87.27	79.51	85.74	95.02	96.42
May 2	52.73	61.83	60.41	61.30	90.91	82.62	88.62	95.88	96.42
May 9	60.44	70.66	72.35	67.51	91.82	88.73	92.30	97.50	98.59
May 16	72.22	75.39	75.64	75.12	94.55	91.94	95.78	98.36	98.59
May 23	86.41	88.64	84.77	82.43	98.18	94.95	98.76	98.92	98.59
May 30	91.60	93.69	92.77	89.73	98.18	97.56	99.34	99.18	98.59
June 6	97.36	99.05	98.43	96.83	99.09	99.17	99.73	99.90	100.00
June 13	99.19	99.68	99.89	97.83	99.09	99.68	99.88	99.97	100.00
June 20	99.61	99.68	100.00	98.74	100.00	99.99	100.00	100.00	100.00
June 27	99.89	100.00	100.00	99.94	100.00	100.00	100.00	100.00	100.00
July 4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The nature of the shelter in which the weevils are hibernating has a decided influence upon the rate of emergence, as is shown in Table XLIV, based upon the experiments of the Louisiana Crop Pest Commission at Mansura, La., in 1909.

TABLE XLIV.—*Effect of nature of shelter upon rate of emergence of the boll weevil, at Mansura, La., 1909.*

Character of hibernating quarters.	Dates by which certain percentages of the surviving weevils were out of hibernation.			
	25 per cent.	50 per cent.	75 per cent.	100 per cent.
Average quarters (cages 5 and 51)	March 19	April 12	May 15	June 27.
Open field (cages A and 5)	March 31	April 29	May 24	June 21.
Swamp (cages Band 51)	April 8	May 20	June 1	June 29.
Moss (cages A and B)	April 13	do	June 2	Do.

It will be noticed that only four cages entered the consideration, cage 5 being average quarters in open field, cage 51 being in average quarters in swamp, cage A being Spanish moss in open field, and cage B being moss in swamp.

SURVIVAL OF HIBERNATED WEEVILS.

The central idea in all the hibernation experiments has been the determination of the percentages of weevils which survive under different conditions and different treatments. In obtaining the facts which have been discussed in the preceding and following paragraphs on hibernation the grand total of 181,932 weevils has been used. With such a large series it is reasonable to suppose that the average percentage of survival must very nearly approximate the normal. This survival in nine series of experiments conducted in seven years at six localities representing the principal climatic, shelter, and other conditions of the infested region has been 7.6 per cent. Table XLV presents the final summaries of each of the nine series.

TABLE XLV.—*Summary of survival of the boll weevil in all the more important experiments.*

Places.	Total number of weevils entering hibernation.	Total number of weevils surviving hibernation.	Percentage of survival.
Keatchie, La., 1906	24,700	731	2.1
Mansura, La., 1909	16,281	3,260	20.0
Mansura, La., 1910	22,179	1,038	4.6
Tallulah, La., 1910	21,835	317	1.4
Tallulah, La., 1911	8,439	46	.5
Five Louisiana series	93,331	5,392	5.7
Dallas, Tex., 1907	32,439	3,464	10.6
Calvert, Tex., 1907	20,430	1,834	8.9
Victoria, Tex., 1907	23,645	3,026	12.8
Dallas, Tex., 1908	12,087	118	.9
Four Texas series	88,601	8,442	9.5
Total of nine series	181,932	13,834	7.6

The highest average percentage of survival for any locality is 20 per cent, at Mansura, La., in 1909, and the lowest average is 0.5 per cent, at Tallulah, La., in 1911. The highest percentage of survival in any cage was 47.72 per cent of 767 weevils, at Mansura, in a cage with average conditions established December 14, 1908. The lowest percentage of survival is no weevils, from 408, at Tallulah, in two cages with average conditions, established November 15, 1910.

RELATION OF FALL DESTRUCTION TO SURVIVAL.

One of the most important recommendations for boll-weevil control is that of early destruction of the cotton stalks. It has long been known that the earlier the stalks are destroyed the less chance the weevils have of surviving. Table XLVI, showing the percentage of emergence by dates of installation, affords an incontrovertible argument in support of this recommendation.

TABLE XLVI.—*Percentage of emergence of the boll weevil, by dates of installation.*

Place.	Sept. 16–30.	Oct. 1–15.	Oct. 16–31.	Nov. 1–15.	Nov. 16–30.	Dec. 1–15.	Dec. 16–31.
Texas points.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dallas, 1907		2.61	6.67	20.57	4.36		
Calvert, 1907		3.15	3.98	10.33	2.65		
Victoria, 1907			6.17	17.69	16.22		
Dallas, 1908	0.23	.39	2.8	1.68	5.26		
Texas, weighted average percentage	.23	2.33	5.62	15.42	16.05		
Total weevils installed	5,213	7,729	27,806	30,431	12,173		
Louisiana points.							
Keatchie, 1906					2.71	3.23	0.8
Mansura, 1909	2.7	3.31	23.9	23.8	24.56	43.23	37.06
Mansura, 1910	.23	1.31	6.58	9.95	6.31	6.79	
Tallulah, 1910	.34	2.23	1.16	1.53	2.4	.00	
Tallulah, 1911		1.15	.54	.00		.00	
Louisiana, weighted average percentage	.37	2.00	8.04	8.82	6.07	10.65	12.61
Total weevils installed	8,186	14,218	24,464	9,620	24,252	10,208	1,483
Grand weighted average percentage	0.31	2.07	6.58	14.26	9.00	10.65	12.61
Total weevils installed	13,399	21,947	52,270	40,051	36,425	10,208	1,483

Converted into terms of the number of weevils in every thousand which would survive the winter if stalks were destroyed on a given date, we can see the force of Table XLVI. It is even more evident from the arrangement of the data given below in Table XLVII.

TABLE XLVII.—*Number of boll weevils in each 1,000 which would have survived destruction of stalks on a given date.*

Date of destruction.	In Texas.	In Louisiana.
September 16–30	2	3
October 1–15	23	20
October 16–31	56	80
November 1–15	154	88
November 16–30	160	60
December 1–15	(?)	106
December 16–31	(?)	126

RELATION OF SHELTER TO SURVIVAL.

It has already been stated that the density of the shelter has a bearing upon the survival. This is best shown by the following records (Table XLVIII):

TABLE XLVIII.—*Relation of shelter of boll weevils to their survival.*

Place.	Date installed.	Weevils.	Shelter.	Survival.
				Per cent.
Mansura, La	October 26	2,436	Average	20.00
Do	do	2,158	Moss	37.76
Victoria, Tex	October 28	2,375	Average	5.61
Do	November 6	2,850	Moss	23.65
Do	November 10	2,850	Average	12.70

RELATION OF CLIMATE TO SURVIVAL.

Another important consideration in determining the causes for high or low survival is the climate. Some of the principal relationships are brought out in Table XLIX below:

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation.*

Place and year.	Description.	Number of weevils.	Per cent of survival.	Periods of emergence.	Rainfall and temperature, Oct. 1–Mar. 15.		
					Rainfall.	Absolute minimum.	Total degrees below 32.
					Inches.	°*F.*	°*F.*
Tallulah, La., 1910–11.	10 cages, variety of shelter, installed Oct. 15–Dec. 1.	8,439	0.5	Feb. 15–June 4	8.30	9.5	199.5
Dallas, Tex., 1907–8.	9 cages, variety of shelter, Sept. 21–Nov. 18.	12,087	.9	Feb. 19–June 16	22.61	15.0	233.0
Tallulah, La., 1909–10.	19 cages, great variety of shelter, Sept. 16–Dec. 14.	21,835	1.4	Feb. 15–June 27	19.34	13.0	378.5

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation*—Con.

Place and year.	Description.	Number of weevils.	Per cent of survival.	Periods of emergence.	Rainfall and temperature, Oct. 1–Mar. 15.		
					Rainfall.	Absolute minimum.	Total degrees below 32.
					Inches.	°*F.*	°*F.*
Keatchie, La., 1905-6.	18 cages, variety of shelter (1 bare), installed Nov. 18–Dec. 18.	24,700	2.1	Mar. 22–June 28..	18.87	21.0	91.0
Mansura, Tex., 1909–10.	19 cages, great variety of shelter, Sept. 16–Dec. 14.	22,179	4.6	Feb. 15–June 15..	15.37	19.5	151.5
Calvert, Tex., 1906–7.	10 cages, variety of shelter, Oct. 1–Dec. 10.	19,408	8.9	Mar. 4–July 1....	11.87	26.0	47.0
Dallas, Tex., 1906–7.	10 cages, variety of shelter, Oct. 13–Dec. 6.	30,864	10.6	Mar. 1–June 19...	8.52	22.0	145.0
Victoria, Tex., 1906–7.	10 cages, variety of shelter, Oct. 25–Nov. 29.	22,463	12.8	Feb. 28–June 15..	11.25	27.0	5.0
Mansura, La., 1908–9.	19 cages, great variety of shelter, Sept. 28–Dec. 21.	16,281	20.0	Feb. 21–June 29..	10.44	23.0	81.0

One of the most striking features of Table XLIX is the disparity between the percentage of survival through the six winters considered. A special effort has been made to discover the factors that cause this disparity. Among those that have been considered are the absolute minimum temperature, the daily accumulated degrees below 32 during the hibernation season, the number of times a temperature below 32° was reached, and the rainfall. Contrary to our expectations, it appears that the number of times the temperature descends below 32° has no direct effect. However, there seems to be a direct relation between the absolute minimum temperature and the rainfall, taken together, and the percentage of survival. As the absolute minimum ascends and the rainfall decreases the survival seems to increase. The greatest survival (Mansura, La., 1908–9) was accompanied by the third highest minimum temperature and the third lowest rainfall during the hibernation season. In the same way the next to the highest survival (Victoria, Tex., 1906–7) was accompanied by the highest absolute minimum temperature and the fourth lowest rainfall. Conversely, the lowest survival (Tallulah, La., 1910–11) was accompanied by the lowest absolute minimum temperature and the lowest rainfall. The next to the lowest survival (Dallas, Tex., 1907–8) was accompanied by the third lowest absolute minimum temperature and the highest rainfall. It thus appears that a moderately cold winter, with temperature frequently near the zone of fatal temperatures and excessive precipitation, is very unfavorable for the weevil, but a winter with little precipitation and a temperature within the zone of fatal temperatures is by far the most fatal. Conversely, a winter with temperatures always above 20° and moderate precipitation is the most favorable for the weevil.

Certain climatic phenomena are likely to occur which will emphasize still more the effects produced by extreme cold and great precipitation. At Tallulah, La., in 1910–11, the early freeze on October 29 cut off the food supply and was followed by warm temperatures in November which required feeding. The minimum experienced in January completed the control and was low enough to counteract the small precipitation.

LONGEVITY OF HIBERNATED WEEVILS.

From the beginning of the hibernation experiments in 1905 it has been the custom to place the emerging weevils in rearing jars or cages to determine the average and maximum longevity with and without food. The data obtained have a bearing upon the proper time for planting and upon other practical points. In these experiments 9,295 weevils have been used, as shown in Table L. The fed weevils were furnished cotton squares as soon as they became available. Before that time they were given fresh cotton leaves daily. The unfed series was supplied with water only. Both series were placed in small cages where general conditions closely approaching those in nature were maintained. It should be especially noted that fed weevils show over double the longevity of unfed weevils throughout the season.

TABLE L.—*Longevity of hibernated boll weevils after emergence.*

Place.	Unfed series.			Fed series.		
	Number of weevils.	Longevity.		Number of weevils.	Longevity.	
		Maximum.	Average.		Maximum.	Average.
		Days.	*Days.*		*Days.*	*Days.*
Keatchie, La., 1906	412	62	17.11			
Dallas, Tex., 1907	2,179	90	12.50	901	130	38.20
Calvert, Tex., 1907	1,079	48	8.07	715	118	30.00
Victoria, Tex., 1907	1,360	44	8.20	1,349	86	14.70
Mansura, La., 1909	261	44	11.09	360	36	10.42
Natchez, Miss., 1909	4	19	8.75	36	25	12.20
Mansura, La., 1910	175	28	8.78	146	81	36.50
Tallulah, La., 1910	179	21	5.70	121	105	22.30
Tallulah, La., 1911	8	12	7.25	10	25	13.30
Total	5,657			3,638		
Maximum		90	17.11		130	38.20
Weighted average			10.55			24.20

It will be noted that the records of longevity of weevils after emergence from hibernation referred to above are based upon specimens that had passed the winter in artificial hibernation cages. However, a number of observations have been made upon the longevity of weevils which pass the winter under natural conditions in the field. For instance, March 1, 1906, a number of weevils were collected from cotton bolls at Brenham, Tex. These were placed in small cages and observed daily. The last one died on May 31. Naturally the time this weevil was deprived of food the preceding fall is not known, but it must have been prior to December 1, as the frosts had

killed all cotton at Brenham by that date. Assuming that it entered hibernation on December 1, it lived six months without food. In another case weevils collected in the field in the spring at Calvert, Tex., lived without food as late as June 8. This gives a duration of life without food of six months and twelve days. Similar observations indicate clearly that the longevity of weevils that pass the winter in artificial cages is a proper index to the longevity of those which pass the winter in the field.

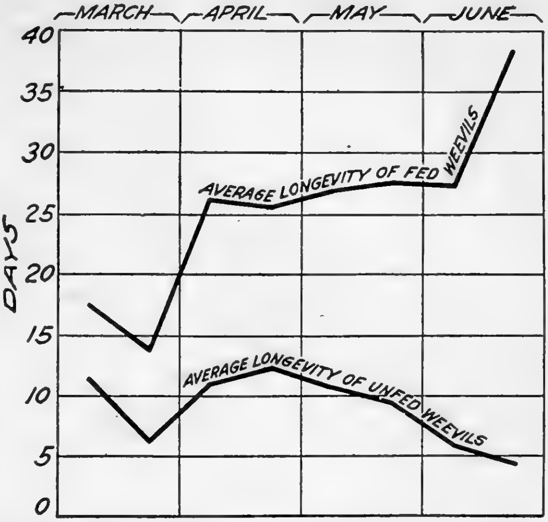


FIG. 25.—Diagram illustrating average longevity of boll weevils after emerging on a given date. (Original.)

It has become quite apparent from a study of the records that the longevity of weevils provided with food is considerably greater with weevils emerging in June than with those emerging in March, while, on the contrary, with unfed weevils the longevity decreases with the lateness of emergence. (Table LI.)

The diagram (fig. 25) illustrates the above statement graphically.

TABLE LI.—*Latest dates of death of hibernated boll weevils.*

Time of emergence.	Unfed weevils.		Weevils fed foliage.		Weevils fed squares.	
	Mansura, La., 1910.	Tallulah, La., 1910.	Mansura, La., 1910.	Tallulah, La., 1910.	Mansura, La., 1910.	Tallulah, La., 1910.
Feb. 15–28	Mar. 18					
Mar. 1–15	Apr. 13	Apr. 1				
Mar. 16–31	Apr. 20	Apr. 12	June 20			
Apr. 1–15	Apr. 28	Apr. 28	July 5	June 21		
Apr. 16–30	May 13	May 21	June 28	June 18		
May 1–15	May 29	June 1	July 15	July 15		
May 16–30	June 12	June 15	July 12	July 26		Sept. 13
June 1–15		June 27	July 29	July 7	July 19	July 1
June 15–30						Aug. 31
Entire season	June 12	June 27	July 29	July 26	July 19	Sept. 13

MAXIMUM LENGTH OF LIFE.

In connection with Table LI it will be noticed that the latest known recorded death of a hibernated weevil is September 13. This fact, taken in conjunction with Table LII, showing the maximum longevity

of weevils from the time of entering hibernation to death, is of great interest. The maximum longevity of 335 days, or 11 months, gives proof of the wonderful vitality of the boll weevil.

TABLE LII.—*Longevity of hibernated boll weevils from installation to death.*

Place.	Condition.	Longevity.	
		Average.	Maximum.
		Days.	*Days.*
Mansura, La., 1910	Unfed	158	226
Tallulah, La., 1910	.....do	169	243
Mansura, La., 1910	Fed foliage	206	256
Tallulah, La., 1910	.....do	221	272
Mansura, La., 1910	Fed squares	257	267
Tallulah, La., 1910	.....do	262	335

RELATION OF EMERGENCE AND LONGEVITY TO TIME OF PLANTING.

The data that have been presented show the extreme importance of early planting as a means of averting damage by the boll weevil. Early planting takes advantage of the portion of the season when the weevils are present in the fields in smallest numbers. The longer planting is deferred the greater the number of weevils which will have emerged. The advantage of an early crop has been shown in many experiments by the Bureau of Entomology and by practical cotton planters. On the other hand, the experience in late plantings has been disastrous. The obvious explanation is in the prolonged period of emergence and the remarkable ability of the weevils to live without food after emergence. This topic will receive additional treatment under the heading of "Repression."

NATURE OF WEEVIL ACTIVITY FOLLOWING EMERGENCE FROM HIBERNATION.

In the section dealing with the spring movement we have discussed the early search of the weevils for food. There are certain points connected with the spring movements, however, which are intimately related to hibernation, and these will be dealt with here.

[1] In following the activity of emerged weevils at Dallas, Tex., certain specimens were marked in such a way as to make it possible to recognize them individually, and the weevils were allowed to remain practically undisturbed in the section where they had spent the winter. In making the daily examinations record was kept of the appearance or disappearance of each individual weevil. No food was supplied in any of the sections until toward the close of the experiments in May, when seed was planted and cotton began growing before the last weevils emerged. A majority of the weevils were seen a second time, and some disappeared and reappeared as many as eight times. The longest period between the first and second appearance of any individual was 43 days.

[1] From Bull. 77, Bureau of Entomology, pp. 50, 51.

TABLE LIII.—*Intermittent activity of unfed boll weevils after emergence, at Dallas, Tex., 1906.*

Number of weevils seen—								Weevils "rehibernated"—						Average survival, number of days.
								Once.		Twice.		Three times.		
Once.	Twice.	Three times.	Four times.	Five times.	Six times.	Seven times.	Eight times.	Number.	Days.	Number.	Days.	Number.	Days.	
46	26	15	11	6	2	2	1	17	8.7	6	7.2	2	3.5	6.8

The observations recorded in Table LIII show conclusively that weevils may leave their winter quarters during warm days and, failing to find food, they may again become quiet and emerge again after a considerable interval. This fact has an important bearing upon the proposition which is frequently advanced by planters of starving the weevils in the spring by deferring the time of planting. While many weevils might perish in this way, it is certain that many more would be able to survive and reappear at intervals, so that there would be plenty of weevils to infest the crop, even though this might be planted as late as is possible to secure any yield.

Other observations were made upon the intermittent activity of unfed weevils during the spring of 1906. Weevils from Calvert, Victoria, and Brenham, Tex., were tested. The weevils from Calvert and Victoria had been confined in hibernation cages throughout the winter. Those from Brenham were collected in the field early in March. None of these weevils had tasted food after emergence. The results are shown in Table LIV. In this table the date of death, unless otherwise indicated, is considered as having been the middle date between the last examination at which a weevil was found alive and that at which it was found dead.

TABLE LIV.—*Intermittent activity of unfed emerged boll weevils, 1906.*[1]

Locality.	When collected.	When put in hibernation.	When removed from hibernation.	When rehibernated.	Weevils put in rehibernation.	Date of first examination.
	1905	1905	1906	1906		
Calvert, Tex.	Nov. 25	Nov. 27	Apr. 19	Apr. 23	20	May 10
Victoria, Tex.	Nov 7, 13; Dec. 11	Nov. 7, 13; Dec. 11	Apr. 6	Apr. 16	7	Apr. 24
	1906					
Brenham, Tex.	Nov. 1	....	Mar. 1	Mar. 7	8	May 11

Locality.	Weevils surviving.	Date of second examination.	Weevils surviving.	Date of third examination.	Weevils surviving.	Date of death of longest survival.	Average length of life in rehibernation.
							Days.
Calvert, Tex.	10	May 22	6	June 8	0	June 8	30.4
Victoria, Tex.	3	May 10	0	....	....	May 10	19.1
Brenham, Tex.	2	May 23	1	May 31	0	May 31	67.4

[1] From Bulletin 77, Bureau of Entomology, p. 52.

The records for Calvert and Brenham show a very remarkable power of endurance in some weevils, the average survival for the two lots of 20 and 8 weevils being over 30 and 60 days, respectively.

NATURAL CONTROL.

Considerable attention has been given to the study of the natural forces which control the boll weevil. These studies have revealed a large amount of important data, some of which have been used in several bulletins. In the present publication it is possible to give only a summary of the most important results.

In general, the natural agencies which control the boll weevil may be classified as climatic (consisting principally of heat which kills directly and also indirectly by rendering the food supply unsuitable, and dryness, the effects of which are intermingled with those of heat), plant resistance, parasites and other insect enemies, diseases, and birds. Each of these agencies will be discussed separately, but a general summarization may be of value. Table LV is a summary of the observations made in the years 1906 to 1909 on weevil stages from many localities. It deals with the mortality of immature stages from all causes exclusive of plant proliferation.

TABLE LV.—*Annual mortality of immature boll weevils in all classes of cotton forms. 1906–1909.*

Year.	Total forms examined.	Total stages found.	Total stages dead.	Number stages killed by—			Percentages of mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
1906	100,644	40,073	22,353	10,078	10,547	1,728	55.81	25.15	26.31	4.31
1907	21,980	13,405	7,275	3,896	2,263	1,116	54.27	29.06	16.88	8.32
1908	72,234	29,546	13,103	6,268	3,878	2,957	44.34	21.21	13.12	10.00
1909	27,857	11,653	4,863	3,012	1,231	620	41.73	25.84	10.56	5.32
1906–1909	222,715	94,677	47,594	23,254	17,919	6,421	50.26	24.56	18.92	6.78

Inasmuch as the material used in making the examinations was derived from many sources and in different proportions each year, a system of weighting the different kinds of material was devised. Table LVI presents a summarization of this weighting in terms of percentages of mortality:

TABLE LVI.—*Weighted average mortality of the boll weevil, 1906–1909, due to various causes.*

Year.	Proliferation.[1]	Climate.	Predation.	Parasitism.	Total.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1906	12.42	24.39	24.85	2.94	64.61
1907	12.42	28.16	16.18	3.83	60.61
1908	12.42	17.83	11.77	6.34	48.37
1909	12.42	23.01	10.92	2.63	48.99
1906–1909	12.42	24.45	15.93	3.93	56.73

[1] The average determined in 1906 (see Bull. 59, Bureau of Entomology) is used to apply to other years.

The extensive series of examinations tabulated above (Table LVI) were made upon immature weevils in all conditions of squares and bolls, the principal of which are known as hanging dry squares, fallen squares, hanging dry bolls, and fallen bolls. The conditions in these four classes of material vary greatly as does the mortality, as is shown in Table LVII. The apparent discrepancy between the totals in Table LVII and in Table LVI is due to the admission of other minor classes of material in the first table. This table (LVII) also excludes mortality from plant proliferation.

TABLE LVII.—*Mortality of immature boll weevils in various classes of cotton forms, 1906–1909.*

Class of infested forms.	Total forms examined.	Total stages found.	Total stages dead.	Number stages killed by—			Percentages of mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
Fallen squares	107,293	63,985	34,403	17,596	13,958	2,849	53.76	27.50	21.81	4.45
Hanging squares	24,683	14,390	7,084	2,543	1,745	2,796	49.22	17.67	12.19	19.43
Hanging bolls	41,738	8,737	3,328	1,709	1,054	565	38.09	19.56	12.06	6.47
Fallen bolls	46,200	6,825	2,375	1,128	1,148	99	34.79	16.52	16.80	1.45
All classes	219,914	93,937	47,190	22,976	17,905	6,309	50.23	24.45	19.06	6.71

Still another extremely important aspect of this large series needs to be shown. This is the geographical differences in the control by climate, predators, and parasites.

TABLE LVIII.—*Average mortality of immature boll weevils in various classes of cotton forms by States, 1906–1909.*

Class of forms and State.	Total forms examined.	Total stages found.	Total stages dead.	Stages killed by—			Mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
Fallen squares.							*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Arkansas	374	162	62	43	17	2	38.27	26.54	10.49	1.23
Louisiana	28,204	15,177	4,895	1,990	2,243	562	32.25	13.11	14.77	3.70
Mississippi	4,216	2,661	1,070	416	263	391	40.21	15.63	9.88	14.69
Oklahoma	657	442	238	100	117	21	53.84	22.62	26.47	4.75
Southwest Texas	2,757	1,390	390	186	152	52	28.06	13.38	10.93	3.74
Southern Texas	38,007	25,063	16,965	8,547	7,377	1,041	67.68	34.10	29.43	4.15
East Texas	825	464	248	136	107	5	53.44	29.31	23.06	1.07
Central Texas	14,879	7,628	4,233	2,386	1,602	245	55.49	31.28	21.00	3.21
Northeast Texas	10,318	6,497	3,439	1,812	1,347	280	52.93	27.89	20.73	4.30
North-Central Texas	7,066	4,501	2,863	1,980	633	250	63.60	43.99	14.06	5.55
Hanging squares.										
Arkansas	1,612	1,144	494	188	60	246	43.18	16.43	5.24	21.50
Louisiana	8,601	5,184	2,182	881	651	650	42.09	16.99	12.55	12.53
Mississippi	784	499	182	41	34	107	36.47	8.21	6.81	21.44
Oklahoma	100	63	26	6	0	20	41.27	9.53	0.00	31.74
Southwest Texas	89	46	24	6	2	16	52.10	13.00	4.30	34.70
Southern Texas	5,740	3,626	1,937	727	496	714	53.41	20.04	13.67	19.69
East Texas	192	135	10	5	1	4	7.40	3.70	0.74	2.96
Central Texas	2,094	1,052	703	253	208	242	66.82	24.04	19.75	22.98
Northeast Texas	4,044	1,667	887	290	211	386	53.80	17.39	12.66	23.15
North-Central Texas	1,992	1,141	766	196	88	492	67.13	17.17	7.71	43.12

Although the grand total of the examinations shows a higher mortality due to fallen squares than to hanging squares, it is noticeable that the mortality in hanging squares is greater in Arkansas, Louisiana, southwestern, central, northeastern, and north-central Texas, and less in Mississippi, Oklahoma, and southern and eastern Texas.

As shown in Table LVIII, the highest mortality in fallen squares is 67.68 per cent in southern Texas and the lowest 28.06 per cent in southwestern Texas. In hanging squares the highest mortality is 67.13 per cent in north-central Texas and the lowest, 7.40 per cent, in eastern Texas.

Climatic control is highest in fallen squares in north-central Texas, at 43.99 per cent, and lowest in Louisiana, at 13.11 per cent, while in hanging squares it reaches 24.04 per cent only in central Texas and is as low as 3.70 per cent in eastern Texas.

Predatory control in fallen squares is highest in southern Texas, at 27.43 per cent, and lowest in Mississippi, at 9.88 per cent, while in hanging squares its highest average is 19.75 per cent in central Texas and its lowest no per cent in Oklahoma.

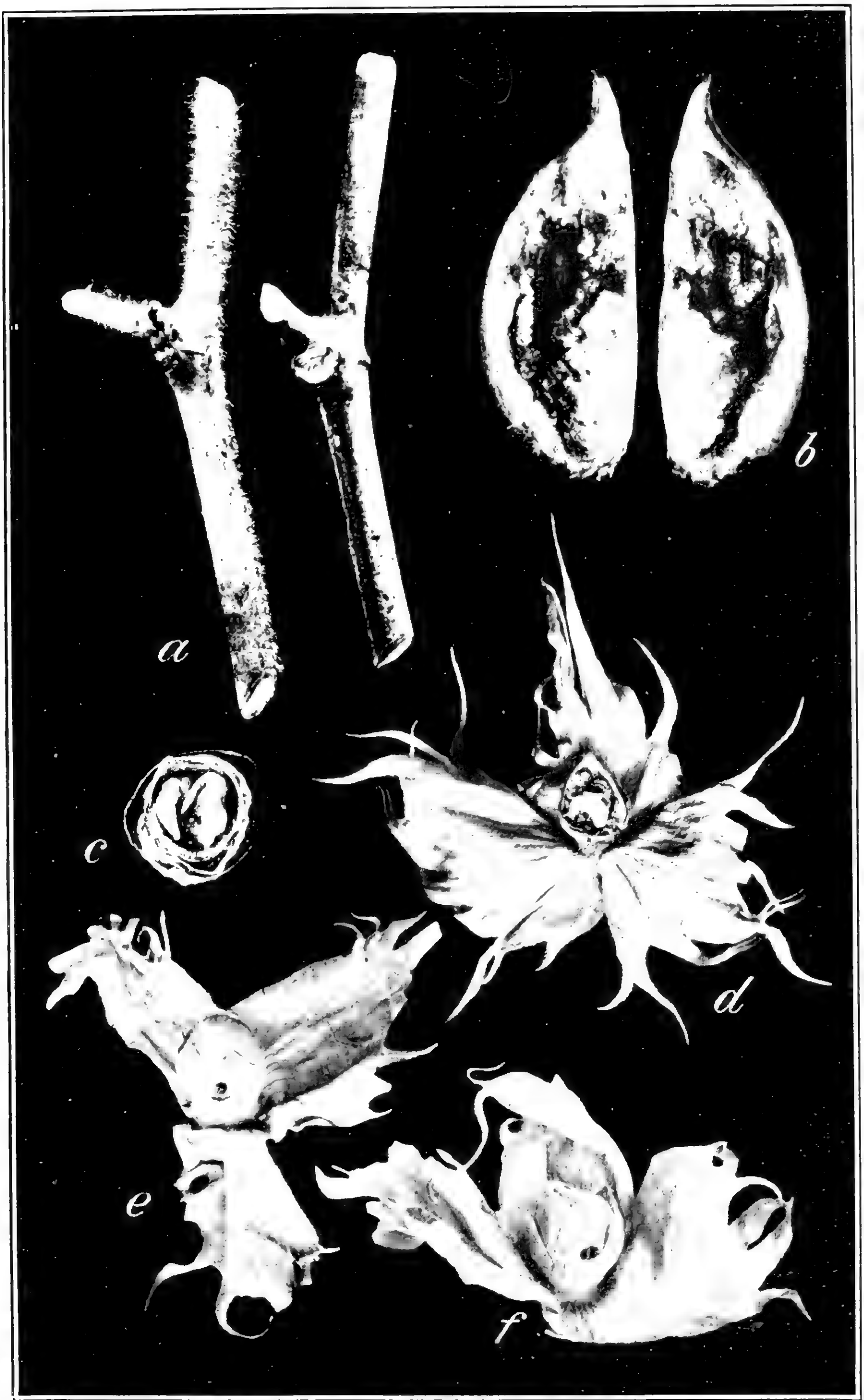
Parasitic control in fallen squares is highest in Mississippi, at 14.69 per cent, and lowest in eastern Texas, at 1.07 per cent. On the other hand, in hanging squares it is highest in north-central Texas, with 43.12 per cent, and lowest in eastern Texas, with 2.96 per cent.

In fallen squares it is generally the case that over half of the mortality is due to climate, but in Louisiana, Mississippi, Oklahoma, and southwestern Texas insect control is greater than climatic. In hanging squares the insect control is invariably greater than climatic control, and in Mississippi, Oklahoma, and southwestern and north-central Texas parasitic control alone is greater than the climatic plus the predatory control. It was shown in the table comparing the total mortality in all classes of forms (Table LVII) that the weighted average mortality due to insects was 25.77 per cent, as against 24.45 per cent due to climate. All of this evidence is cited to show that in reality the insect enemies produce a very large proportion of the mortality of the boll weevil and should therefore be encouraged in every way possible. Of course, it is evident that climatic control is even superior, because of the influences it brings to bear upon every phase of the weevil's existence.

Regional comparisons such as have been made above are of the greatest importance in determining what factors in natural control need to be given the greatest encouragement by cultural expedients or otherwise.

CLIMATIC CONTROL.

From almost every viewpoint the climatic control of the boll weevil is the most important which this insect experiences. The weevil reacts to a multitude of conditions of temperature and humidity. The time of entrance into hibernation, the length of the hibernation period, the time of emergence from hibernation, the length of the various immature stages, the rate of oviposition, and even the proportion of sexes are profoundly affected by these agencies. In many cases their effects are not direct. They may affect the weevil indirectly through the cotton plant. For example, drought may interfere with the fruiting of the cotton plant and thus deprive the weevils of food.



NATURAL CONTROL OF THE BOLL WEEVIL.

a, Pilose and nonpilose stems of cotton; *b*, larva of boll weevil crushed by proliferation; *c*, pupa of *Catolaccus incertus* on pupa of cotton boll weevil; *d*, larva of *Microbracon mellitor* attacking boll-weevil larva; *e, f*, holes gnawed by *Solenopsis geminata* in effecting entrance into infested squares. (Original.)

The most conspicuous illustration of the climatic control of the weevil lies in the failure of the pest to establish itself in the drier portions of Texas. For several years multitudes of weevils have flown from the more humid portions of Texas to the west, where the climate is drier. In fact, every year there has been a large inflow of weevils into this region. Every season, however, the conditions have practically immediately prevented the establishment of the weevil. The most important factor has been dryness, but there are others that must be considered. Among them is the fact that there is comparatively little winter protection for the insect. In addition, an indirect result of small precipitations is the growth of cotton plants of only small size. This results in a small amount of shade and thus augments the direct effect of heat and dryness upon the infested squares which fall to the ground.

Frequently the effects of climate act upon the enemies of the boll weevil. This is the case where heat destroys the weevils and their parasites in squares that fall to the ground. In several cases, however, heat increases the effectiveness of the enemies of the weevil. A striking example of this was observed on September 2, 1911, by Mr. J. D. Mitchell, of the Bureau of Entomology. A succession of days in which the temperature was very high and the air exceedingly dry caused the premature opening of many cotton bolls in the vicinity of Victoria, Tex. Prior to this time the weevils had destroyed practically all of the squares, and many immature stages were to be found in the bolls thus forced open. In such instances the exposed immature stages of the weevil were subjected to two important destructive agencies. Heat killed many that became exposed to the air, and the ants were able to reach not only those that were exposed, but others inside of the partially opened bolls. If the bolls had not opened, such weevils would have been beyond the reach of the ants. As it was, the climatic conditions not only directly destroyed large numbers of weevils in a situation where climatic factors rarely affect them, but also greatly increased the effectiveness of another unrelated factor of control.

CLIMATIC INFLUENCES ON VITALITY AND ACTIVITIES.

In the preceding pages numerous effects of climate upon the development and activities of the boll weevil have been pointed out, but these must be summarized in order to show how intimately connected the climate is with every phase of the weevil's life. It appears that the movements of the weevil are sluggish or active in accordance with the nature of the day, cloudy days or low temperatures always causing them to be more sluggish. The number of feeding punctures per square decreases with increases in temperature, and the time before falling of a punctured square also decreases with higher temperatures. In like manner the length of life of the weevil decreases. The age of beginning copulation and the age of beginning oviposition are both increased by decreases in temperature. The activity in oviposition, which is found to begin at 75° F., is greatest in the hottest time of the day, cloudy days causing the oviposition to be less active. The number of eggs per day increases with the temperature and varies for any given temperature with the humidity. The entire period of development increases as the temperature and atmospheric humidity decrease.

The number of generations decreases with the mean temperature and mean humidity.

Hibernation seems to begin at mean temperatures between 56° F. and 60° F., but is hastened by high humidity. Cold nights followed by warm, still days seem to stimulate the weevils to considerable activity in the fall, evidently warning them to seek hibernation quarters. The period of entrance into hibernation is much more rapid as the mean humidity and mean temperature become lower. The emergence of the weevil is in like manner influenced by the temperature, but it must be considered that the actual temperature experienced by the weevil is that which affects the emergence. The time of emergence apparently depends upon an accumulation of a certain amount of effective temperature and a certain amount of rainfall, but if more than the necessary temperature accumulates less rainfall will be needed, and vice versa. The majority of weevils emerge at mean temperatures between 64° F. and 78° F. The percentage of survival seems to decrease as the absolute minimum temperature decreases and the rainfall increases.

The foregoing statements are conclusions based in some cases upon more or less fragmentary information, but in other cases they may almost be considered as laws of climatic control.

FIELD OBSERVATIONS ON MORTALITY DUE TO HEAT AND DRYNESS.

Heat and dryness affect the weevil in a very simple manner. Unless the square remains moist the food supply becomes unsuitable. In other cases the heat itself causes death directly. Therefore, the hotter and drier the ground upon which the infested square falls, the more certain is the death of the weevil.

In the years 1906 to 1909 an exhaustive study was made of the effects of various climatic and other agencies which control the boll weevil. In this work 222,715 cotton forms (including bolls and squares) were collected by agents of the Bureau of Entomology at 65 localities in Texas, 26 in Louisiana, 7 in Oklahoma, 6 in Arkansas, and 6 in Mississippi. Careful laboratory observations were made to determine the mortality due to heat or dryness and to other factors.

By reference to the series of general tables (LV–LVIII) at the beginning of the discussion of natural control it will be noticed that climatic control kills practically one-fourth of the developing stages, the average for the four years in which records were made being 24.56 per cent, which was slightly surpassed by the total insect control. The highest average climatic control was obtained in 1907, being 29.06 per cent, while in 1908 it averaged only 21.21 per cent.

In rearranging the data to ascertain the condition in which the control was greatest we find the following results: Fallen squares, 27.50 per cent; hanging dry bolls, 19.56 per cent; hanging dry squares, 17.67 per cent; and fallen bolls, 16.52 per cent.

The geographical distribution of climatic control is very interesting. In fallen squares the various sections ranked as follows: North-central Texas, 43.99 per cent; southern Texas, 34.10 per cent; central Texas, 31.28 per cent; eastern Texas, 29.31 per cent; northeastern Texas, 27.89 per cent; Arkansas, 26.54 per cent; Oklahoma, 22.62 per cent; Mississippi, 15.63 per cent; southwestern Texas, 13.38 per cent; Louisiana, 13.11 per cent.

In hanging squares we find a somewhat different arrangement of the sections: Central Texas, 24.04 per cent; southern Texas, 20.04 per cent; northeastern Texas, 17.39 per cent; north-central Texas, 17.17 per cent; Louisiana, 16.99 per cent; Arkansas, 16.43 per cent; southwestern Texas, 13 per cent; Oklahoma, 9.53 per cent; Mississippi, 8.21 per cent; and eastern Texas, 3.70 per cent.

In many of the records made during 1906 it became evident that certain cultural practices greatly favored the amount of control by heat and dryness. The wider the rows, the greater the amount of sunlight which strikes the ground. Consequently the fields with wide rows or in which the stand was imperfect showed the greatest mortality. In a similar way, fields in which were varieties with comparatively small amounts of leafage showed greater mortality due to heat and dryness. It did not become apparent, however, from the observations made, that the direction in which the rows ran made any material difference in the mortality.

The difference between the various sections in the mortality in fallen squares is especially conspicuous. This is due undoubtedly primarily to the greater precipitation in the sections with low mortality, which, by keeping the ground more or less moist, prevents such temperatures at the surface as are frequently reached in Texas. The greater rainfall in Louisiana also undoubtedly has an indirect effect. In that State the additional rainfall causes the cotton plants to grow to a large size and to shade the ground more than is the case in Texas, thus preventing the sun from reaching the squares on the ground. The differences in hanging squares are not quite so conspicuous, but are probably due to some extent to atmospheric humidity, density of foliage, and other similar factors.

Equally interesting results were obtained in 1906 with reference to the effect of heat and dryness upon the different stages of the boll weevil. It was found that the mortality in the larval stage amounted to 52 per cent, in the pupal stage to 18 per cent, and in the adult stage to 6 per cent. Nearly 70 per cent of all the mortality caused by heat and dryness occurs, therefore, during the larval stage.

Table LIX illustrates the percentage of stages killed during the warm months of the year by high temperatures and is based upon all of the examinations made during the years 1906 to 1909, inclusive.

TABLE LIX.—*Weighted average heat control of immature stages of the boll weevil, by months, Texas, Louisiana, Oklahoma, Arkansas, and Mississippi.*

Month.	Forms examined.	Stages found.	Per cent killed by heat and drying.
May	100	56	7.20
June	16,930	10,708	28.33
July	43,059	21,758	25.61
August	80,923	33,170	24.62
September	37,378	17,107	22.87
October	17,344	8,283	16.59
Total	195,734	91,082	23.80

Many illustrations are available to show the powerful effect of heat and dryness in the reduction in the numbers of boll weevils in cotton fields. The action of this agency is so powerful that it may check the

weevils in a single season so that a crop may be obtained. This was shown in a field which was under observation in Victoria County, Tex., in 1906. It was found in April that a very large number of hibernated weevils appeared in the field. This month was reasonably moist, so that the cotton germinated promptly and made a quick growth. The month of May, however, showed a decided deficiency in precipitation, being more than 3 inches below the normal for the month. This checked the weevil at the time the first infested squares began to drop. The control continued during the month of June, which also showed 3 inches less than the normal rainfall. These conditions resulted in such a checking of the weevils by June that the cotton plants were able to put on a large number of squares. The month of July showed a precipitation above the normal, which caused the plants to grow rapidly. The setback experienced by the weevils, however, during the preceding dry period was so great that they were unable to overtake the production of fruit, so that a yield of about one-fourth of a bale per acre was obtained.

Examples of such complete control within a single season are not common. It frequently happens that a drought continues so long that the plants are seriously affected. In general, however, the plants can recover more rapidly from a drought than the weevil. This results in an advantage to the crop from even a short drought. Of course the advantage becomes greater as the drought is prolonged, provided it is not prolonged to a point where it seriously affects the growth of the plants. Examples of the control of the weevil in one season from heat and dryness of the preceding season are common. Table LX shows a striking instance of this kind. It will be seen that the effects of the drought of 1902 extended into the following season and brought about a marked increase in production. By the following year (1904) the recovery of the weevils from the drought of 1902 was indicated by a decreased production of cotton.

TABLE LX.—*General illustration of drought control of the boll weevil, Nueces County, Tex., 1901–1904.*

Year.	Rainfall.				Temperature.				Cotton production, Nueces County, equivalent in 500-pound bales.
	Annual.		Mar. 1–Aug. 31.		Annual.		Mar. 1–Aug. 31.		
	Mean average.	Departure from normal.	Mean average.	Departure from normal.	Mean average.	Departure from normal.	Mean average.	Departure from normal.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	
1901	17.49	−11.90	6.74	− 7.42	70.7	0.0	76.2	+0.83	601
1902	22.22	− 7.98	5.57	− 7.39	71.5	+1.4	77.3	+1.85	480
1903	36.92	+ 6.72	25.97	+11.38	69.1	− .9	74.5	− .9	4,099
1904	28.54	− 1.66	13.56	+ .83	70.5	+ .4	76.0	+ .5	1,556

GENERAL DISCUSSION OF THE RELATIONS OF TEMPERATURE TO THE BOLL WEEVIL.

Our studies of the boll weevil lead us to the conclusion that there is a certain degree of temperature above which, under any condition of humidity, no individuals can exist even for a limited time. This point is known as the *maximum fatal temperature*. Below this there is a zone of varying width of temperatures which may be fatal in cases of long exposure or under certain conditions of humidity or insect vitality. This may be known as the *upper zone of fatal temperatures*. Below the zone of fatal temperatures is a zone of temperatures which, when continuing for any length of time, force the insects to shelter. This zone may therefore be fitly called the *zone of æstivation*, and it must be understood that the relative humidity will have a strong influence in moving this zone upward or downward, according to regional conditions. This zone is limited by the point at which effective temperature ceases. Below this point is the *zone of activity*. In this zone will be found the degree of effective temperature, a long continuance of which is necessary to draw the insects out of hibernation. This is not an absolutely fixed point, for it varies with humidity.[1] Possibly the relation could be stated in a definite formula if a sufficient amount of data was available.

The temperature which causes activity is usually known as the *zero of effective temperature*. It is assumed that active metabolism begins at this point and that a certain amount of effective temperatures accumulated in daily units is necessary to bring about a given transformation or function. This sum is known as the *total effective temperature* for any given function. It will vary in accordance with the humidity. Below the zero of effective temperature there will be no necessity of feeding, and locomotion rapidly becomes impossible. On the approach of the zero of effective temperature the insects will display considerable activity in finding winter quarters. We therefore designate the zone below this zero as the *zone of hibernation*. The lower limit of this zone is the highest temperature which may be fatal under certain conditions of humidity or rapid alternation of temperatures. Below this point occurs a more or less restricted *lower zone of fatal temperatures*. The lowest point at which life can exist is known as the *minimum fatal temperature*.

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[1] Of course the manifestation of the absolute temperature which draws the weevils out of hibernation is dependent upon the density of shelter. Certain forms of shelter prevent the weevils from being affected until long after the outside air has been sufficiently warm to cause activity.

These zones are illustrated in the accompanying diagram (fig. 26).

UPPER ZONE OF FATAL TEMPERATURE.

Numerous experiments have been conducted in dropping adult boll weevils upon the soil at different temperatures to determine the effects upon the insect. In this work 119 tests were made at soil temperatures varying from 110° to 140° F. Below 122° F. none of the weevils were killed, but from 122° F. upward death resulted in times varying from 1 second to 900 seconds. In a general way the exposure necessary to cause death decreased as the temperatures became higher. From these experiments we conclude that the upper zone of fatal temperature for the adult boll weevil may be considered as from 122° to 140° F.

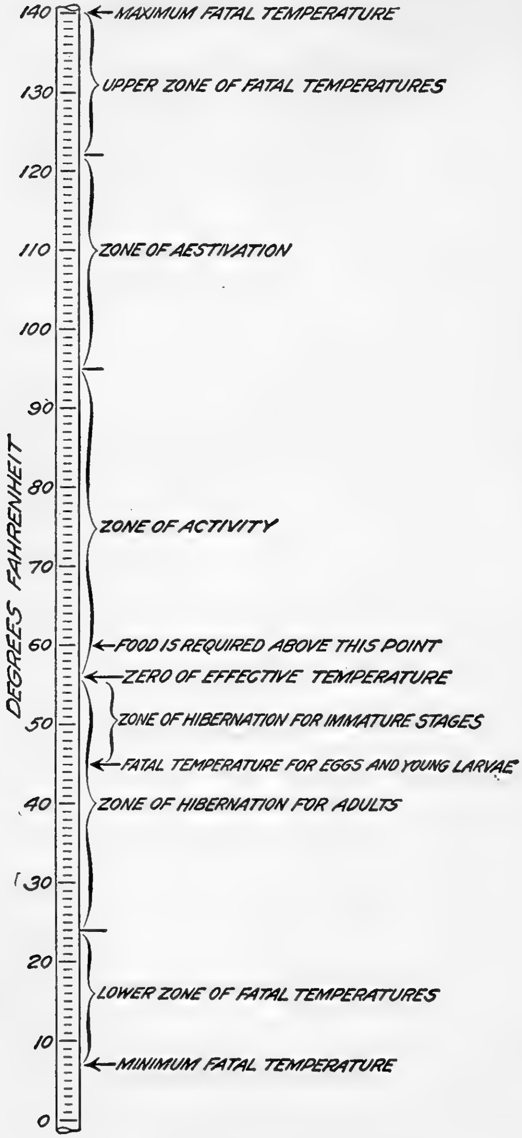

FIG. 26.—Diagram to illustrate the zones of temperature in their relations to the activities of the boll weevil. (Original.)

In the series of experiments to which reference has been made a number of observations were made upon humidity. The atmospheric humidity during the time the experiments were under way, however, was rather constant, ranging from 37 per cent to 40 per cent. Within this narrow range it was not determined that humidity either decreased or increased the length of time necessary to cause the death at any fixed temperature.

It is interesting to note that the zone of fatal temperature for adult weevils which fall to the ground will be reached under general conditions when the temperature recorded at the usual distance above ground at which thermometers are placed reaches 95° F.

ZONE OF ÆSTIVATION.

During 1906 and 1907, in southern Texas, Mr. J. D. Mitchell observed that many adult weevils were on the ground near the cotton stalks under clods of earth and dead leaves, seeking protection from the intense heat. This indicates a distinct zone of æstivation, although such temperatures may exist only for a few hours at a time. The exact limitations of this zone are undeterminable. Æstivation is a very common habit among weevils. As throwing some light on the probable action of the boll weevil under high temperatures, it is of interest to state that Prof. C. H. T. Townsend, of Piura, Peru, finds that the Peruvian cotton square borer, *Anthonomus vestitus* Boheman, æstivates during the hot months in the fallen squares both as pupa and adult, but remains practically inactive.

ZONE OF ACTIVITY.

The temperatures at which most of the functions of the boll weevil are exercised lie between the means of 91° F. and 56° F. It is probable, however, that this zone approaches very close to the zone of fatal temperatures. In the spring effective temperature [1] begins to accumulate at approximately 56 degrees, but the total necessary to bring the weevils out of hibernation may be low if the rainfall and humidity for the same period are high, and it must be correspondingly high if the humidity is low.[2] When the two factors have accumulated enough between them they bring about emergence. It is roughly calculated that 172° of effective temperature and 5.1 inches of rain are necessary. A deficiency of effective temperature must be balanced by additional rainfall; a deficiency of rainfall must be balanced by additional effective temperature. For a fuller discussion of this subject see the section on emergence from hibernation (p. 107).

When the weevils have emerged and found food they require a certain number of days of feeding before oviposition can take place. This preoviposition period for hibernating weevils and for the succeeding generations is determined largely by temperature and humidity. As these two factors decrease the period increases. In like manner we have shown on preceding pages how the egg and larval and pupal stages are governed by the same laws. We have also shown that even the daily rate of oviposition is accelerated by increases in temperature and probably also of humidity.

The common impression that "rain brings the weevils" has its basis in the natural increase in the numbers of weevils shortly after a rainy period, due somewhat to the fact that increased humidity reduces the developmental period. A more important factor, however, is that humidity reduces the effects of sunshine in killing the weevil stages.

ZONE OF HIBERNATION.

The behavior of the weevils in hibernation is fully discussed elsewhere. In ice-box experiments at 45° F. it was found that the weevils would not emerge, but Dr. W. E. Hinds found that 10 weevils which had emerged from hibernation and which were confined 303 weevil

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[1] That is, the temperature at which activity begins.

[2] In a former publication (Bull. No. 51) we adopted the assumption made by other writers that 43° F. is the general zero of effective temperature for insects. Recent experiments have shown conclusively that this is an error, so far as the boll weevil is concerned.

days at 44° to 45° F. made 36 feeding punctures, or at the rate of one puncture every 8.4 days. It is probable that these punctures were all made possible by the removals from refrigeration for examination.

LOWER ZONE OF FATAL TEMPERATURES.

In 1904 Dr. W. E. Hinds conducted experiments in the effects of low temperature on eggs and young larvæ. He found that 34 eggs at 45° F. for 13 to 14 days did not hatch when kept later at a temperature of 69° to 70° F. Recently hatched larvæ, however, were killed by nine days' exposure to 45° F.

By experiments conducted with adults in 1905 it was ascertained that 32° F. was not fatal; 24° F. benumbed the weevils, but they could revive; 18° F. killed.

In experiments conducted by Mr. H. P. Wood 32 weevils were exposed to a minimum of 15° F. and an average temperature of 18.6° F. for seven and one-fourth hours and then placed in the refrigerator at a higher temperature, but none recovered.

In similar experiments Mr. W. A. Hooker exposed 11 weevils for six hours to temperatures varying from 15° to 20° F. The weevils were quiet, but later showed signs of life, although they died within two days. Between 7 and 10 degrees, five weevils were killed in six hours. One degree below zero was absolutely fatal.

Observations on the effects of low temperatures upon the weevils in the fields leads to the statement that all places experiencing a temperature under 12° F. in the early part of the winter will profit by an almost complete extinction of the weevil, depending somewhat, of course, upon the amount of protection the weevils may have secured before the freeze. Regions having a normal minimum temperature of zero need have little fear of serious continued depredations from the weevil until the insect has proved itself able to adapt itself to colder temperatures than it is now able to withstand.

In this connection it will be of interest to submit Table LXI, giving the average winter mortality from cold since the beginning of our records.

TABLE LXI.—*Weighted average cold control of immature stages of the boll weevil, by months.*

Month.	Forms examined.	Stages found.	Killed by cold and wetting.
			Per cent.
January	5,687	1,285	36.42
February	13,597	665	67.36
March	2,500	159	31.44
November	2,534	798	41.40
December	2,663	688	38.37
Total	26,981	3,595	44.61

It should be noticed that winter cold is, on the average, almost twice as effective as summer heat.

The history of the boll weevil furnishes several examples of winter control, principal among which are the early freezes of November, 1907, November, 1908, and December, 1909, which greatly reduced weevil damage in large sections.

FATAL VARIATIONS OF TEMPERATURE.

It has long been known that one of the most potent forces in insect control is abnormal variation of temperature. Probably no stronger illustration of such control could be produced than that afforded by the conditions of the winter of 1910–11.

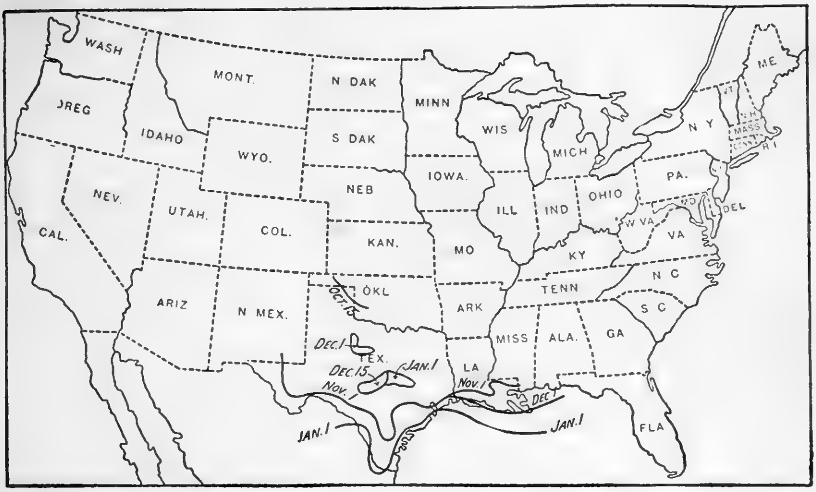


FIG. 27.—Map showing dates of first killing frost in the area infested by the boll weevil, in the winter of 1909–10. (Original.)

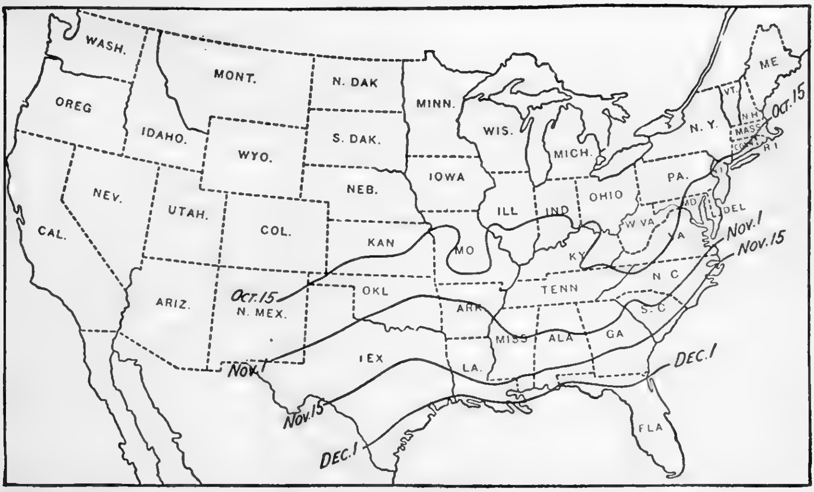


FIG. 28.—Map showing normal dates of first killing frost in the southern United States. (After Weather Bureau Bulletin V.)

On October 29 to 30, 1910, a freeze occurred throughout the cotton belt affecting all but a narrow strip of territory along the Gulf coast and two small interior areas of Texas, as illustrated by the accompanying map (fig. 27). Another map (fig. 28) is presented to show

the normal dates of the first killing frosts. Comparison of these two maps will show at a glance that the first killing freeze of 1910 was over a month earlier than the normal. Such a natural phenomenon is an exact equivalent of artificial fall destruction at the same date. The temperatures were not fatal to the weevils, but were such as to force hibernation and at the same time cut off food supply. If temperatures compelling hibernation had continued, the weevils would have emergep in about the same proportion as would be expected if they were artificially deprived of food on the same date. However, another climatic factor intervened. Almost the entire month of November was warm, and throughout Louisiana, at least, the mean temperature stood at above 56° F. for the month. We have already shown that a continuance of mean temperatures over 56° F. will force the weevils to take food, and that in the absence of food at effective temperatures starvation occurs in a few days. If all of the cotton had been killed by the freeze, the control would have been complete, but there are always sheltered areas on hillsides or near buildings that escape two or three severe freezes, and these areas no doubt harbored many weevils until the cold wave of November 29 drove them to a normal hibernation.

FIG. 29.—Map showing minimum temperatures on October 29 and 30, 1910, the date of the first killing frost in Louisiana. (Original.)

In the map (fig. 29) showing the Louisiana minimum temperatures of October 29 and 30, 1910, on which dates the first killing frost occurred, it will be noticed that no fatal temperature was reached, but that a freezing temperature occurred in practically all of the cotton-producing territory. The other map (fig. 30) illustrates the minimum temperatures of the entire winter of 1910–11 and shows that fatal temperatures (7° F. to 22° F.) occurred throughout the State. These minima

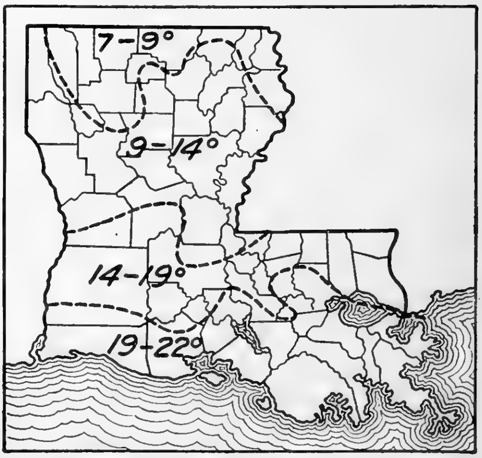


FIG. 30.—Map showing minimum temperatures in the winter of 1910–11 in Louisiana. (Original.)

occurred, however, early in January, at which time all weevils which had survived the starvation of the fall were deeply hidden in hibernation shelters, where sudden changes of temperature have little effect.

The survival from hibernation at Tallulah, La., was only one-half of 1 per cent, as shown in the hibernation statistics, and this, no doubt, must be attributed to the rare combination of early freeze, subsequent long duration of effective temperatures without food, and finally a period of minimum fatal temperatures.

One of the most interesting features of the fall of 1910 in Texas was the presence of two small areas in which the first freeze was delayed from one to two months. (Fig. 27.) We call attention to the most interesting of these cases. The freeze of October 29 was felt in all Texas above the latitude of 31°, except in Erath, part of Comanche, part of Brown, Eastland, Callahan, Taylor, Jones, and Haskell Counties in central-west Texas. In this frost-free area in the following October, 1911, a very heavy infestation was found at Cisco, in Eastland County, and at Brownwood, in Brown County. The infestation diminished in every direction from those places. At Lampasas, 60 miles southeast of Brownwood, where we would naturally expect a much higher infestation than at Cisco, very slight damage occurred, and at Granbury, in Hood County, 60 miles east of Cisco, where the weevils have been present since 1904, they were extremely difficult to find. Thus, it is seen that a territory which had had the weevil much longer than either Brownwood or Cisco had fewer weevils in 1911, because it experienced an earlier killing frost.

EFFECTS OF FLOODING UPON THE WEEVIL.

Tests at Victoria, Tex., in 1904, were divided into two parts, each of which included both the immature and mature stages. In each part floating and submergence were tested. In the tests made upon the floating power of adults, weevils were isolated and placed in water in tumblers. They were dropped from a considerable distance above the surface, so that they became entirely submerged, and they rose to the surface naturally. The surface tension of the water was found to be sufficient to float weevils which were placed upon it carefully. The generally hairy condition of the surface of the weevil's body prevents it from being readily wetted, so that it may struggle for some time in the water without becoming really wet. When dropped, as described above, weevils float head downward, with the tip of the abdomen above the surface. In the submergence tests weevils were held down by a wire screen, and all bubbles were removed from their bodies by a pipette, thus making the tests as severe as possible.

Sixty squares believed from external examination to be infested were floated in a driving rain for six hours. They were then removed and left for several days, during which time 75 per cent of them produced normal adults. Ten squares which were floated in driving rain for six hours were opened at once, and in every case found to be only slightly moist on the inside. These contained six larvæ and four pupæ, and all were in perfect condition.

As squares float normally, submergence tests were considered extreme. Five squares were submerged for six hours, and after that produced three normal adults; one pupa died, and one square was found

to have been uninfested. Five more squares were submerged for 31 hours. These produced two normal adults, and one pupa died in the process of molting after removal from the square. Death was probably caused in the last case by drying; one square was found to contain a dead pupa, and one was not infested. To test the possibility of its living, should the square be penetrated by water, a naked pupa was submerged for six hours, but in spite of this unusual treatment it produced a normal adult. Numerous larvæ removed from squares and placed in water pupated in one or two days, and several pupæ remained alive, though floating for several days in water before they transformed into adults.

In the case of squares floating normally it is evident that they might remain in water for several days without injury to the weevil within. Very slight wetting of the cell takes place, even under the extreme conditions of submergence. The effect of a brief flood would not, therefore, be at all injurious. As adults float as readily as do squares, they may also be carried long distances, and, furthermore, they are able to crawl out of the water upon any bushes, weeds, or rubbish which they touch. Even when floating for several days continuously they are able to live and may be carried directly to new fields. The floating of adults and infested squares explains the appearance of weevils in great numbers along high-water lines immediately after a flood.

Field observations were made to supplement the laboratory experiments recorded in the preceding paragraphs. In July, 1904, many fields in the vicinity of Victoria, Tex., were partially and some wholly submerged. This condition lasted for several days. Examination made after the recession of the water showed that many fallen squares which had been in the water for some time contained uninjured larvæ and pupæ. Naturally, eggs and larvæ found in squares upon the plants, even though under water for some time, escaped unharmed. Weevils were working normally upon the plants. No diminution in their numbers could be seen, and it was apparent that the overflow caused no check either to the development of the immature stages or to the activity of the adults.

PLANT CONTROL.

While climate is the foremost factor in the control of the boll weevil and also of the behavior of the cotton plant, there are certain kinds of control which the plant itself exerts. One of the most important of these is proliferation, which will be discussed in the following paragraphs.

PROLIFERATION.

Early in the investigation of the boll weevil it was noticed that the immature stages and sometimes even the adults are frequently killed by a form of reaction of the plant known as proliferation.[1] It appears that this property of the plant might be emphasized by breeders. For this reason special studies were conducted in 1905

[1] Dr. O. F. Cook, of the Bureau of Plant Industry, has published a number of papers in which references are made to proliferation. The reader is referred to these papers, which are included in the bibliography at the end of this bulletin, for a full discussion of the botanical aspects of the phenomenon.

and 1906. The results were published in Bulletin 59 of the Bureau of Entomology from which the following statements are abstracted.

For the present purposes proliferation may be defined as the development of numerous cells from the parts of the bud or boll of the cotton plant which are injured by the weevil. It is clearly a manifestation of an inherent tendency on the part of the plant to counteract irritation by the growth of large numbers of new cells. This growth usually begins in the layer of cells adjoining the lining of the boll or in the staminal column of the undeveloped bloom. Part of the formation may project through the rupture made by the weevil or may form a hemispherical mass protruding from the inner side of the carpel of the boll and pressing into the lock. The reaction on the part of the plant begins generally before the egg hatches. In some cases the egg itself may be moved a considerable distance by the growth. In other instances the egg becomes enveloped and the larva emerges in the proliferous mass. Under such circumstances it may be destroyed early in life, although it often makes its way through the mass into portions of the fruit which have not been affected. As the larva feeds it continues and increases the irritation, and the response of the plant is immediate. In this way it often happens that the space the larva has eaten out becomes filled by the proliferous mass, and the pressure becomes so strong that eventually the larva or the resulting pupa or adult is crushed. It is clear from the observations made that it is this crushing effect that destroys the weevil. (See Pl. XIV, *b*.) A number of experiments in which weevil larvæ were placed in proliferous tissues showed that they could develop normally upon this modification of their natural food.

The frequency of the occurrence of proliferation was determined by the examination of 1,870 squares and 2,042 bolls of a large number of American and several foreign cottons. In the case of squares, it was found that in the averages for all seasons and localities proliferous growth followed feeding punctures in 48 per cent of the cases. The highest percentage, 75, was in the case of the Jannovitch, an Egyptian variety. In the case of bolls, proliferation followed in 81 per cent of the cases of feeding punctures. It is consequently apparent that proliferation occurs more frequently as a result of feeding punctures in bolls than in the case of punctures in squares.

No very satisfactory results followed a study of the effect of climatic conditions upon the frequency with which proliferation follows the attack of the weevil. The observations included a number of varieties growing in two localities during two seasons, but there seems to be no special relation between the locality and the season and the number of cases in which proliferation was found. In fact, the maximum percentage of formation of proliferation in bolls and the minimum in squares occurred at the same time in the same locality and with the same variety.

Table LXII shows the weevil mortality due to proliferation in squares and bolls under natural conditions.

TABLE LXII.—*Summary of observations showing increased mortality of the boll weevil in squares and bolls caused by proliferation.*[1]

Years of observations.	Localities covered.	Varieties included.	Squares examined.			Mortality in squares.		Increase in mortality due to proliferation.	Bolls examined.	Locks examined.			Mortality in locks.		Inhrease in mortality due to proliferation.
			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.	
						P.ct.	P.ct.	P.ct.					P.ct.	P.ct.	P.ct.
1902	4	4	105	44	41.9	30.5	19.5	11.0							
1903	1	1							246	1,033	434	42.0	15.0	5.0	10.0
1903	1	1							452	1,898	995	52.4	28.4	12.8	15.6
1904	1	9	2,954	1,480	50.0	9.6	.6	9.0							
1904	2	2							398	1,708	885	51.8	18.2	11.1	7.1
1905	1	14	4,504	2,365	52.5	19.6	5.5	14.1							
1905	1	6	771	372	48.2	28.6	.3	28.3							
1905	1	1	443	212	47.9	25.1	9.7	15.4							
1905	1	4	144	40	27.8	34.8	3.2	31.6							
1905	1	14							1,802	7,821	5,069	64.8	16.7	8.5	8.2
1905	1	1							82	254	158	62.2	14.6	.0	14.6
Totals and averages			8,921	4,513	[2] 50.6	[2] 17.2	[2] 3.7	[2] 13.5	2,980	12,714	7,541	[2] 59.3	[2] 15.5	[2] 9.2	[2] 6.3

[1] From Bulletin 59, Bureau of Entomology, p. 27.

[2] Weighted average.

It will be seen that in the case of squares there was a range of from 9 to 31 per cent increase in the mortality due to proliferation, the general average being 13 per cent. In bolls the range is not so great, being only from 7 to 15 per cent, while the average increase in mortality in bolls was found to be 6 per cent. This is slightly less than one-half as great a mortality as was found to be the case in squares.

A number of interesting experiments were performed to determine whether artificial punctures were as frequently followed by proliferation as those made by the weevil. One thousand one hundred and three needle punctures were made, resulting in proliferation in 36 per cent of the cases. This percentage is not so large as in the case of feeding punctures of the weevil, but it is as large as could be expected when the difference between a clean needle puncture and the rough, lacerating puncture by the weevil is considered. It consequently appears that it is the mechanical injury of the weevil rather than any secretion which causes the growth. A further series of experiments showed that injections of caustic potash, formic acid, and other chemicals did not appear to increase the number of cases in which proliferation followed. It did appear, however, that unsealed artificial punctures resulted in more frequent proliferations than sealed punctures of the same kind.

A number of experiments were instituted to show the possible effect of heavy fertilization of the cotton plant upon its tendency to form proliferous tissues. It was supposed that some such cultural expedient as fertilization might increase the resistance on the part of the plant. In the case of over 8,000 observations made on fertilized cotton growing in two localities, however, it was found that proliferation followed attack by the weevil practically as frequently in the one case as in the other. Squares on fertilized plats showed proliferation in 50.5 per cent of the cases; on unfertilized plats in 49.5 per

cent. Bolls on fertilized plats showed proliferation in 66.2 per cent of the infested locks; on unfertilized plats in 69.5 per cent.

It was found that proliferation very frequently follows the attacks of any of the insects which injure the cotton boll or square. In the case of these other insects the phenomenon is of little importance, since, unlike the weevil, they generally make punctures merely for the purpose of feeding. The immature stages are not developed in the cotton fruit and are consequently beyond the reach of the growth which the adults have incited.

OTHER PHASES OF PLANT CONTROL.

There are other forms of plant control which require attention. Dr. O. F. Cook, of the Bureau of Plant Industry, has been the principal student of this matter and has called attention to numerous weevil-resisting adaptations of the cotton plant, although important contributions have been made by several other investigators. Among the more important properties or tendencies of the cotton plant which affect the weevil adversely are: (1) Early bearing, (2) determinate growth, (3) hairy stalks and stems (Pl. XIV, *a*), (4) abundance of secretion from nectaries, (5) pendent bolls, (6) involucral bracts grown together at base, (7) thick-walled bolls, and (8) tendency to retain infested fruit (Pl. XV).

Early bearing enables the plant to produce its fruit before the weevils have become numerous. In other words, it allows the plant to take advantage of the small number of weevils which succeed in passing the winter and also to take advantage of the comparatively slow development of the insect during the early portion of the growing season.

Determinate growth prevents the maturity of numerous weevils in the fall. Plants with this character well marked discontinue both growth and fruiting. As the capacity of the weevil to increase is limited very largely by the amount of fruit available, it is evident that a variety which discontinues fruiting at an early date in the fall must reduce greatly the number of weevils that are present to go into winter quarters.

It has been found that the presence of a considerable growth of hair on the stalks and stems presents an important obstacle to the progress of the weevil and consequently reduces the daily capacity of damage of each insect. In some of the American upland varieties, notably the King, this hairiness is developed to such an extent as to be a form of protection of considerable importance.

As has been pointed out in another section of this bulletin, boll-weevil parasites in the adult stage feed upon the nectar which is secreted by the cotton plant. Consequently the greater the secretion of nectar the more favorable will be the conditions for these important enemies of the weevil.

There is a more or less constant tendency on the part of the adult weevil to frequent the upper portion of the cotton plant. If it happens to alight upon a lateral branch which has bolls or squares standing upright, attack follows immediately. On the other hand, if the branch upon which the weevil alights has bolls which turn downward, there is a considerable likelihood that it will work upward to other lateral branches and overlook the fruit upon the first branch.

The weevil has frequently been observed to experience considerable difficulty in reaching the cotton square through the involucral bracts. If these bracts are united at the base, or very closely appressed, or have their edges provided with strong hairs, the natural difficulty the weevil experiences will be increased.

Dr. Cook has pointed out that certain Central American strains of cotton have bolls provided with thick interior walls, which in some cases the weevil is unable to penetrate.

As has been pointed out in another section, the insect enemies of the boll weevil find the infested squares which remain on the plants more suitable for attack, and are able to raise the average control above that in fallen squares in most sections. Consequently it is of advantage to the planter to have a variety with a well-marked tendency to retain the infested fruit. The ability to retain the infested squares is explained under the heading of parasite attack (p. 144).

Several other peculiarities of the cotton plant which Dr. Cook has interpreted as weevil-resisting adaptations are described in Bulletin 88 of the Bureau of Plant Industry of this department.

DISEASES.

Little attention has been given to the study of diseases of the boll weevil because the observations upon the mortality of the insect have not indicated any great amount of death due to causes which could not be well explained under the headings of climatic, plant, parasitic, and predatory control. There is no doubt that bacterial and fungous diseases sometimes attack the weevils, especially those hibernating in moist places. Only two definite records are at hand of death by fungus, and these have been recorded in former bulletins. One was a case of a new species of Aspergillus and the other of a species of Cordyceps.

PARASITIC AND PREDATORY INSECT ENEMIES.

Recent work has added very greatly to our knowledge of the insect enemies of the boll weevil. Much remains to be done, however, since it has been found that the boll weevil is accumulating species after species of parasites as it advances farther into the United States. A recent publication of this bureau (Bulletin No. 100) has dealt rather extensively with the insect enemies of the boll weevil. In the present publication, therefore, only a few of the more important facts learned will be considered.

A BRIEF SUMMARY OF THE INSECT SPECIES ATTACKING THE BOLL WEEVIL.

At the present time the boll weevil is known to be the host of 29 species of parasites, of which 4 are mites, 21 belong to the order Hymenoptera, and 5 are parasitic flies. In addition to these true parasites, there are 6 predators which kill the adult boll weevils and 22 predators which attack the immature stages. These include a mantis, a predatory bug, 8 beetles, a leaf-feeding caterpillar, and 17 species of ants. In all, the boll weevil is known to have 58 species

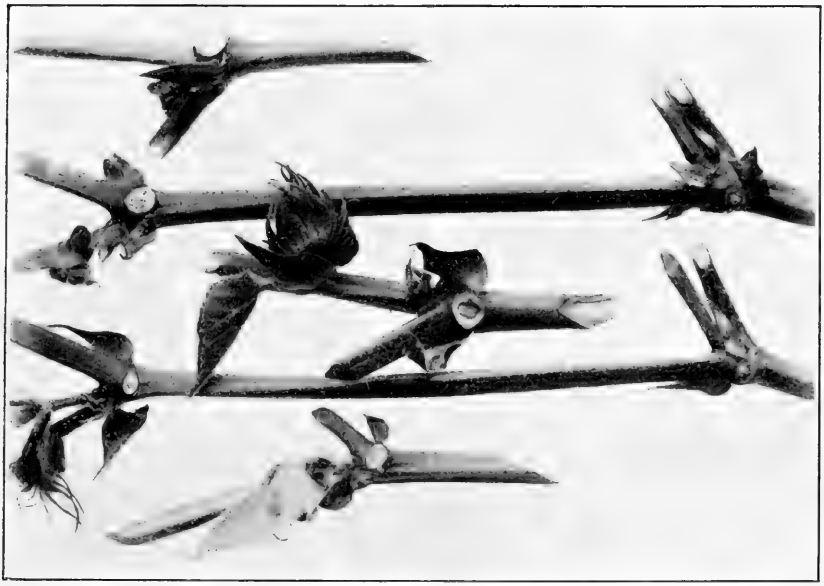


Fig. a.—Cotton squares with short absciss layer, permitting infested squares to fall. (Original.)

Fig. b.—Cotton squares with long absciss layer, retaining infested forms to hang and dry. (Original.)

THE DIFFERENCE BETWEEN HANGING AND FALLEN SQUARES.

of insect enemies, and probably many more species will be found as the weevil enters new regions. In fact, records of parasite and ant attack have been found as early as two weeks after invasion of new territory.

ARACHNIDA. ACARINA. SARCOPTOIDEA.

Pediculoides ventricosus Newport.—This mite has been prominent in the study of the boll weevil since its first notice (Rangel, 1901) under the name of *Pediculoides ventriculosus*. These mites reproduce viviparously, and their offspring are mature and fertile at birth. After attachment to a host the abdomen begins to inflate until it becomes many times greater than the thorax. The time required for engorgement varies from two to five days. An average of 100 female offspring to an individual has been recorded.

Pediculoides n. sp.—This mite was discovered in the laboratory at Dallas, Tex., June 13, 1907, by the junior writer. Observations continued for some time proved that there was a generation about every four days. The mite has been found attacking several other species of weevils as well as many other insects.

Tyroglyphus breviceps Banks.—This species has been recorded as an enemy of the boll weevil from Victoria, Tex. A similar mite has also been found at Calvert, Tex.

GAMASOIDEA.

Macrocheles n. sp.—Mr. Harry Pinkus found this mite very common in the fallen cotton squares at Tullulah, La., during August, 1911, feeding upon the boll-weevil stages. It has not been definitely proved that the species kills the weevil, but the evidence is more or less conclusive.

INSECTA. ORTHOPTERA. MANTIDÆ.

Stagmomantis limbata Hahn.—This insect has been found to prey upon the adult boll weevil in Texas.

HETEROPTERA. REDUVIIDÆ.

Apiomerus spissipes Say.—This predatory bug has been recorded by Mr. A. C. Morgan as an enemy of the adult boll weevil in Texas.

COLEOPTERA. CARABIDÆ.

Evarthrus sodalis Le Conte.—This species (fig. 31) is a predator upon the adult boll weevil in Louisiana and Texas.

Evarthrus sp.—Another species of the genus has been recorded by Newell and Trehearne as predatory upon adult boll weevils at Baton Rouge, La.

CANTHARIDÆ.

Chauliognathus spp. (see fig. 32).—The larvæ of these beetles are very common in the squares and bolls of cotton in Louisiana and Mississippi. In one instance undoubted proof of the attack of such a larva upon a boll-weevil larva was recorded.

CLERIDÆ.

Hydnocera pallipennis Say.—A single beetle of this species was reared April 6, 1907, from the boll weevil, collected August 28, 1906, at Waco, Tex.

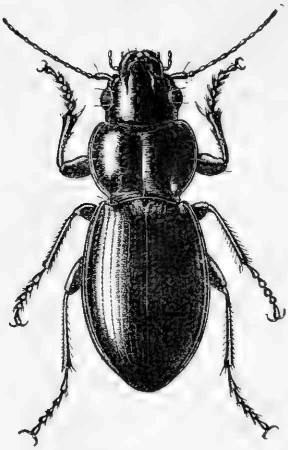


FIG. 31.—*Evarthrus sodalis*, an enemy of the boll weevil. (Original.)

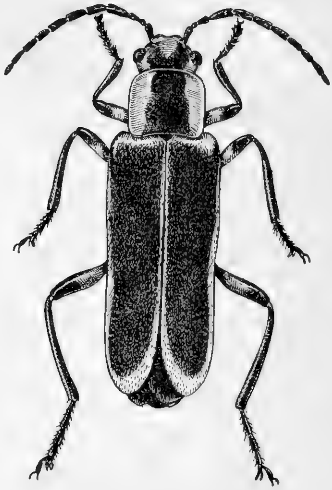


FIG. 32.—*Chauliognathus marginatus*, an enemy of the boll weevil. (Original.)

Hydnocera pubescens Le Conte (fig. 33).—This is a very common breeder in the weevil cells. Its larvæ have been not only found feeding upon the various weevil stages, but have been frequently observed feeding upon the parasites of the weevil.

CUCUJIDÆ.

Cathartus gemellatus Duval.—This beetle is a predator and scavenger, its larvæ being frequently found feeding upon boll-weevil stages which they must have killed.

TENEBRIONIDÆ.

Opatrinus notus Say.—This beetle has been found by Mr. Harry Pinkus at Tallulah, La., to prey as an adult upon the immature stages of the weevil in fallen squares during July. It occurred very commonly in the cotton fields.

LEPIDOPTERA. NOCTUIDÆ.

Alabama argillacea Hübner.—For many years the ravages of the cotton leaf worm attracted almost as much attention in some portions of the South as does the damage by the boll weevil now. Various changes in the system of cultivation of cotton in the South have combined to reduce the damage done by this pest, and, moreover, a very effective method of controlling it, by the use of Paris green, was discovered. It is one of the striking occurrences in the history of economic entomology that this formerly dreaded pest is now looked upon by the farmers in weevil-infested regions as decidedly beneficial.

When the plants become defoliated by the leaf worms the growth is checked, and consequently the opportunities for the breeding of the weevils in additional squares are reduced. This results in a marked decrease in the number of weevils at the end of the season. This decrease has not so much effect upon the crop of the current year as upon the following one by reason of the lessened number of weevils that pass through hibernation. Moreover, when the plants have been deprived of most of their leaves the worms very frequently devour the squares and sometimes small bolls in which the immature stages of the boll weevil are located. In this way the leaf worm acts directly as a remedial agency against the boll weevil. This work to some extent accomplishes the same result as the fall destruction of the plants, which, as is well known, is the greatest single factor in the successful production of cotton in weevil-infested regions. There is still another consideration in this connection, namely, that the defoliation of the plants allows the sun to strike the squares upon the ground, thus destroying many of the larvæ and pupæ of the weevil contained therein. At the present time, as the result of the conditions mentioned, the planters in the infested regions are rapidly giving up the practice of poisoning the formerly much dreaded caterpillar. If, as may occasionally happen, the plants become defoliated before the weevils reach the maximum numbers in the fields, the damage of the one insect will simply be added to the damage of the other. In that event the use of poison will be necessary.[1]

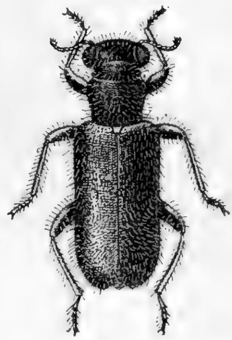


FIG. 33.—*Hydnocera pubescens*, an enemy of the boll weevil. (Original.)

In the extensive defoliation by the leaf worm in 1911 one of the most striking features was the scattering of the boll weevil for great distances into new territory. The general absence of green fields caused the weevils to fly much farther than they would otherwise have done.

HYMENOPTERA. FORMICOIDEA. DORYLIDÆ.

Eciton (*Acamatus*) *commutatus* Emery (Pl. XVI, *a*).—This ant has been observed only once, at Beeville, Tex., attacking the weevil larvæ in squares.

PONERIDÆ.

Ectatomma tuberculatum Olivier.—The "kelep," or so-called Guatemalan ant, is a native of Mexico and Central America. Like all other ponerids, it is slow in action, but is able to capture such weevils as come within its reach on the cotton plants. Numerous attempts to establish this species in the United States have failed.

MYRMICIDÆ.

Cremastogaster lineolata Say, subsp. *læviuscula* Mayr, var. *clara* Mayr. (Pl. XVI, *b*).—This ant, although normally a honeydew feeding species, is also an enemy of the immature stages of the boll weevil in Texas.

Solenopsis geminata Fabricius, var. *diabola* Wheeler.—The common fire ant of the Southern States is one of the best enemies of the boll

[1] The above paragraph is from W. D. Hunter in the Yearbook of the Department of Agriculture for 1904, p. 201.

weevil, being very industrious in its search for infested squares, which it enters in great numbers.

Solenopsis molesta Say (Pl. XVI, *e*).—This minute ant was taken in the act of attacking a boll-weevil larva at McAlester, Okla., by Mr. R. A. Cushman.

Solenopsis texana Emery.—This ant is a common enemy of the immature stages of the boll weevil in Texas, Louisiana, and Mississippi.

Monomorium minimum Buckley.—The common house ant is a very valuable enemy of the boll weevil in Texas, Louisiana, and Mississippi.

Monomorium pharaonis Linnæus (Pl. XVI, *d*).—This cosmopolitan house ant is another of the more important boll-weevil enemies in Texas, Louisiana, and Arkansas.

Pheidole sp. near *flavens*.—This species was found abundantly attacking the immature stages of the boll weevil at Arlington, Tex., August 31, 1908, by Mr. R. A. Cushman.

Pheidole crassicornis Emery.—This species was found as an abundant enemy of the immature stages of the weevil at Lampasas, Tex., September 23, 1908, by Mr. R. A. Cushman.

DOLICHODERIDÆ.

Forelius maccooki Forel.—This ant has been recorded at several places in Texas as an enemy of the immature stages of the boll weevil.

Dorymyrmex pyramicus Roger (Pl. XVI, *c*).—The so-called lion ant of Cuba was recorded by Mr. E. A. Schwarz (1905) as protecting solitary tree cotton from the boll weevil.

Dorymyrmex pyramicus Roger, var. *flavus* Pergande.—This common cotton-field ant has only once been recorded definitely as an enemy of the boll weevil. This record is from Texarkana, Tex., by Mr. R. C. Howell.

Iridomyrmex analis Ern. André. (Pl. XVI, *f*).—This common ant is normally a honey-loving species, but occasionally attacks insect food. It has been found attacking the boll weevil by Dr. W. E. Hinds.

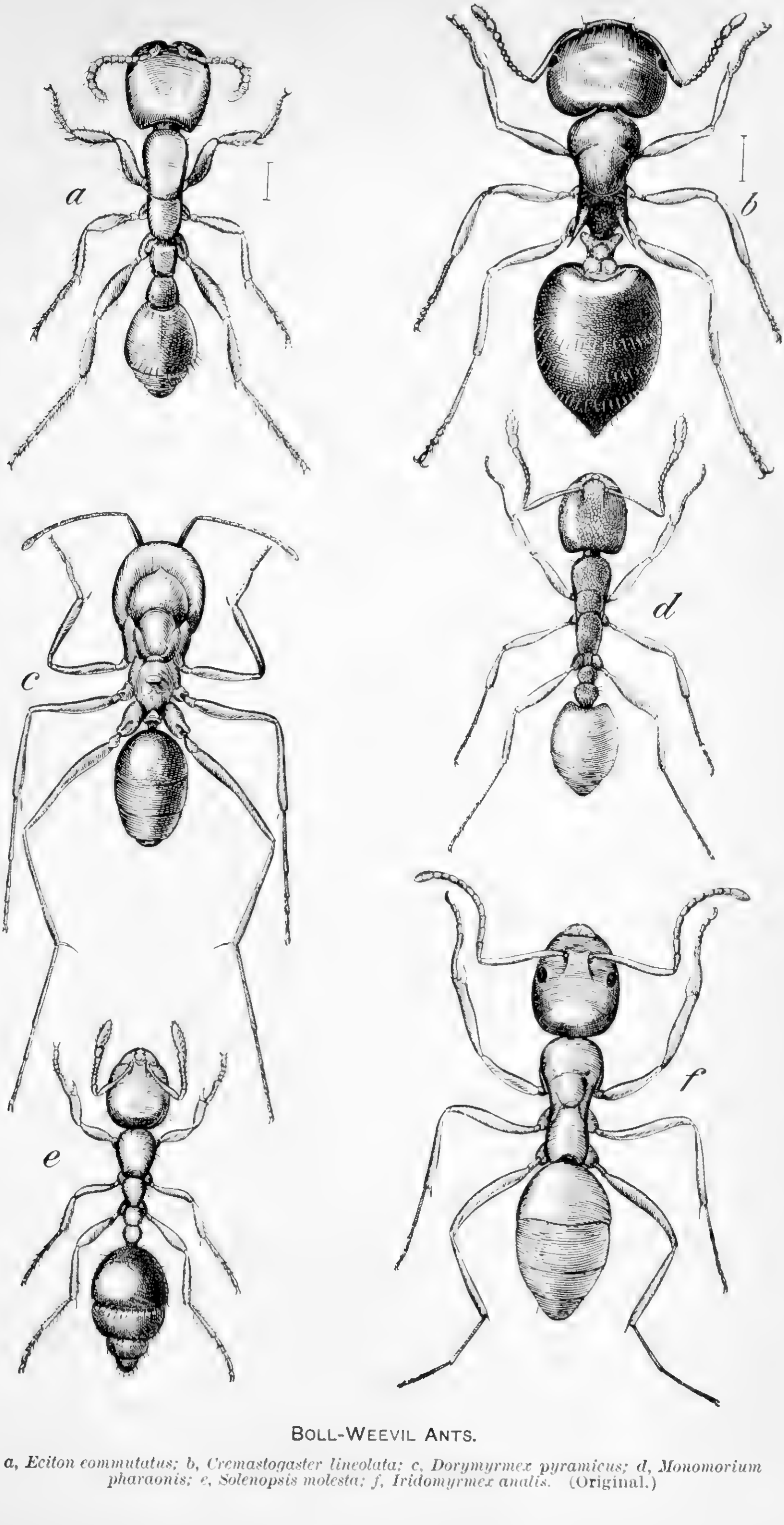
Iridomyrmex humilis Mayr.—The Argentine ant has formerly been recorded as an enemy of *Solenopsis geminata*, *Monomorium pharaonis*, and *Iridomyrmex analis*, three of our common boll-weevil enemies. Mr. T. C. Barber has recently reported that the Argentine ant, by continually worrying the boll weevils and killing newly emerged adults, practically cleared a heavily infested cotton patch at Baton Rouge, La., in September, 1909, at a time when fields outside of the ant territory were still very seriously infested.

FORMICIDÆ.

Formica subpolita Mayr, var. *perpilosa* Wheeler.—This species is normally a honey feeder, but has been recorded by Rangel (1901) as a predator upon adult weevils in Mexico.

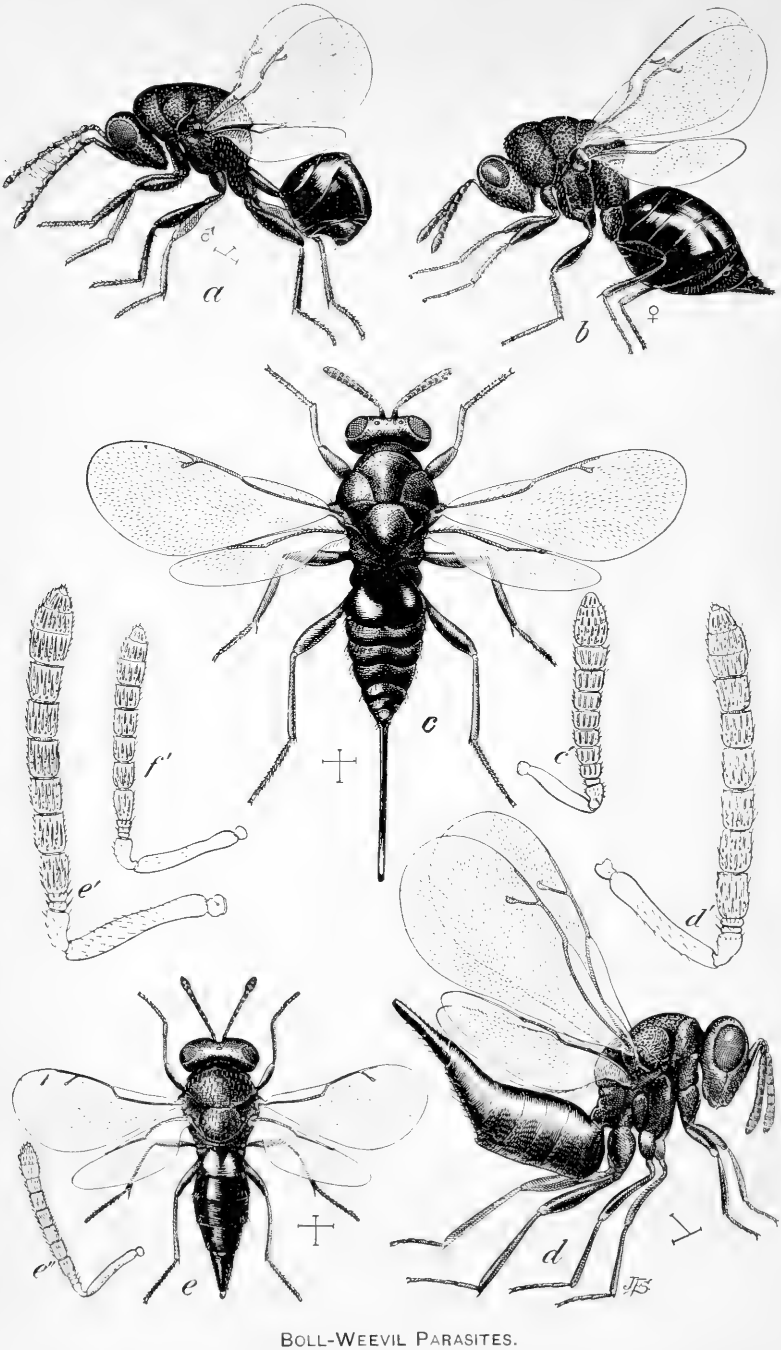
Formica pallidi-fulva Latreille.—A single instance of this species cutting its way into a boll weevil-infested square was observed by Mr. C. E. Hood at Ashdown, Ark., September 2, 1908. The species is commonly found on the cotton plants.

Prenolepis imparis Say.—Mr. C. E. Hood recorded this species as an enemy of the immature stages of the boll weevil at Ashdown, Ark., September 2, 1908.



BOLL-WEEVIL ANTS.

a, Eciton commutatus; b, Cremastogaster lineolata; c, Dorymyrmex pyramicus; d, Monomorium pharaonis; e, Solenopsis molesta; f, Iridomyrmex analis. (Original.)



BOLL-WEEVIL PARASITES.

a, *Eurytoma tylodermatis*, male; *b*, *Eurytoma tylodermatis*, female; *c*, *Microdontomerus anthonomi*, female; *c′*, antenna of same; *d*, *Habrocytus piercei*, female; *d′*, antenna of same; *e*, *Catolaccus hunteri*, female; *e′*, antenna of same; *f′*, antenna of *Catolaccus incertus*. (Original.)

HYMENOPTERA. CHALCIDOIDEA. CHALCIDIDÆ.

Spilochalcis sp.—A single male of this species was found dead in a weevil cell with the remains of the weevil and its own exuvium August 10, 1907, at Victoria, Tex.

TORYMIDÆ.

Microdontomerus anthonomi Crawford (Pl. XVII, *c*).—This is one of the most important parasites of the boll weevil in Texas and Louisiana. It is generally found throughout the year and is known to attack two other species of weevils.

EURYTOMIDÆ.

Eurytoma tylodermatis Ashmead (Pl. XVII, *a*, *b*).—This species ranks among the five most important boll-weevil parasites, and its range is practically coextensive with that of its host. It is known to attack 14 other species of weevils.

Eurytoma sp.—Two species of this genus were reared from hanging squares collected August 10, 1907, at Victoria, Tex.

Bruchophagus herreræ Ashmead.—This parasite has been recorded from the boll weevil from Mexico, but the name is thought to be a synonym of *Eurytoma tylodermatis*.

PERILAMPIDÆ.

Perilampus sp.—A single individual was reared from the boll weevil by isolation from material collected September 7, 1907, at Shreveport, La., by Mr. C. E. Hood. Considerable doubt has been raised concerning this record by authorities upon the breeding habits of Perilampidæ.

ENCYRTIDÆ.

Cerambycobius cyaniceps Ashmead (Pl. XVIII, *f*).—The range of this species is coextensive with the boll weevil in the United States. It is extremely important in northern Louisiana and Arkansas, and is known to attack 17 species of weevils.

Cerambycobius cushmani Crawford.—This species is evidently limited to southern Texas, where it is occasionally important. It is known as a parasite of four other species of weevils.

Cerambycobius sp.—On February 23, 1909, a male of a green species of this genus was reared from a weevil in squares collected at Natchez, Miss., on January 19.

PTEROMALIDÆ.

Catolaccus hunteri Crawford (Pl. XVII, *e*).—This is one of the most important parasites of the boll weevil. It is of greatest importance in Louisiana and Mississippi. Twelve other species of weevils are known as hosts.

Catolaccus incertus Ashmead (Pl. XVII, *f′*).—This is also a very important species and occurs throughout the infested region. It is also a parasite of 13 other species of weevils.

Habrocytus piercei Crawford (Pl. XVII, *d*).—This brilliant green parasite has been reared from the boll weevil only in the fall and winter months in Louisiana and Texas. One other weevil host is known.

Lariophagus texanus Crawford (Pl. XVIII, *a*).—There is strong evidence that this species is a primary parasite of the boll weevil in southern Texas. It is also undoubtedly a parasite of four other species of weevils.

EULOPHIDÆ.

Tetrastichus hunteri Crawford (Pl. XVIII, *b*, *c*).—This parasite of the boll weevil has been known only since 1908. It is the only internal hymenopterous parasite of the weevil and occurs commonly in Louisiana and Mississippi and has been recorded from Texas. It is evidently more important in the fall of the year.

ICHNEUMONIDEA. ICHNEUMONIDÆ.

Pimpla sp.—On February 23, 1909, a single female of this species was reared from a weevil larva collected at Nacogdoches, Tex., on January 27.

BRACONIDÆ.

Sigalphus curculionis Fitch.—This common parasite of the plum curculio has been found frequently attacking the boll weevil in Louisiana and Mississippi. It is known as a parasite of eight other species of weevils.

Urosigalphus anthonomi Crawford.—This species has been reared from the boll weevil only at Brownsville, Tex.

Urosigalphus schwarzi Crawford.—This species is a parasite of the boll weevil in Guatemala and has never been reared in the United States.

Urosigalphus sp.—A single specimen of this species was reared in 1909 at Arlington, Tex.

Microbracon mellitor Say.—Until 1909 this was the most important parasite of the boll weevil. It is coextensive in distribution with its host, but is by far most important in Texas and Oklahoma. It is known as a parasite of 10 other species of weevils.

An unknown braconid, nearly related to Glyptocolastes, was reared from the boll weevil in southern Texas.

DIPTERA. PHORIDÆ.

Aphiochæta nigriceps Loew.

Aphiochæta fasciata Fallen.

Aphiochæta pygmæa Zetterstedt.

These three species and also possibly others in this genus have frequently been found feeding upon boll-weevil larvæ and in many cases under such circumstances that they must be assumed to be parasites as well as scavengers.

TACHINIDÆ.

Myiophasia ænea Wiedemann.—This fly has been recorded as a parasite of the boll weevil in Texas. It is also an enemy of six other species of weevils.

Ennyomma globosa Townsend (Pl. XVIII, *d*, *e*).—This fly is an important parasite of the boll weevil in Louisiana. It also attacks the cowpea curculio.

Careful studies have proved that the 29 species of parasites are all derived from native hosts, which are mainly weevils breeding in weeds and other plants growing normally around the cotton fields. Some of these parasites have lived for many generations on certain common weevils until suddenly some abnormal condition has decimated the numbers of the normal hosts or freed the parasites of their normal control, thus upsetting the natural equilibrium between them and their hosts. In this way the parasites have been compelled to seek new hosts, and the presence of the boll weevil in large numbers has led them to attack it. This has been demonstrated by the sudden adaptation of several species of parasites at Victoria, Tex. These were normally enemies of the huisache pod weevil, but were unable to attack this insect in 1907 because of the failure of the huisache trees to fruit. Another demonstration of sudden adaptation was found in the sudden increase of attack by *Eurytoma tylodermatis* following the cutting of a number of weeds in which this parasite was attacking a native weevil. Such adaptability of course suggests the advisability of keeping the weeds in the vicinity of cotton fields cut down during the summer in order to force the parasites to attack the boll weevil.

After a parasite has once attacked a new host it becomes comparatively easy for succeeding generations to repeat the attack. In this manner many species of weevil parasites have increased their range of hosts until they have obtained a complete series extending throughout the year. A rotation of hosts has, therefore, been established. As many as 17 different weevils are attacked by one of the species of boll-weevil parasites. To illustrate the value of this rotation we have but to quote one of the commonest examples. The strawberry and blackberry bud weevil is very common in the South in the latter half of March and until June. Two of the species of the boll-weevil parasites attack this weevil as soon as it begins to breed, and they are able to develop at least one generation before the boll weevil can begin its attack on the cotton squares. These parasites are found attacking the boll weevil throughout the summer. In the fall they begin to attack certain stem weevils, such as the potato or Solanum stem weevils, and produce a generation during the winter which emerges in time to attack the strawberry weevil. Thus, two generations are developed while the boll weevil is in hibernation. To obtain a practical benefit from this rotation of hosts it is only necessary to have a hedge of dewberries or blackberries along the fences.

It is of extreme importance to know that no matter what exigencies reduce the boll weevils, the parasites, though also reduced in numbers, will still be conserved on their native hosts and will attack the boll weevils again as soon as they become sufficiently numerous.

The location of the developing stages of the weevil is of much importance to the insect enemies. (See Pl. XV.) It has been found that cotton varieties display two distinct tendencies in their response to injury to their fruit. Certain varieties, such as King, Simpkins, and Shine, are distinguished by a transverse ring at the base of the pedicel of the square and boll. When the square or boll is badly injured, the plant immediately cuts off circulation by forming a corky layer at this ring, and the injured member falls to the ground. Other varieties, such as Dickson, Rublee, and in general the cluster

and semicluster types, are distinguished by an elliptical mark which encircles the pedicel, but extends down the stem for one-half to a whole inch or more, and is usually incomplete at the lower end. When such a square is injured, the corky layer is of course diagonal, extending downward on the stem, but usually incomplete, so that the injured member adheres by a thread of bark and dries on the plant. A very extended series of observations has definitely proved that the hanging dry infested square is the most favorable place for parasitic control and that the total control of the weevil by all causes increases in proportion to the number of these hanging dry infested squares. A proper selection of varieties is, therefore, a practical method of increasing control.

On the other hand, it must be understood that insect control of the stages in fallen squares is often very high. Certain parasites and all of the ants and predatory beetles are more likely to find the immature weevils in the soft moistened or dried fallen squares than in the dry hanging squares. Thus the developing weevil has enemies wherever it is. The parasite control on the ground will be obtained best by the methods of cultivation to be mentioned hereafter.

The adjustment of new species of parasites and predators in each new region makes it apparent that the boll weevil will everywhere be attacked by those species of insects most fitted to attack it under the existing local conditions. This attack will be of greatest importance in regions where humidity tends to reduce the effectiveness of other forms of control.

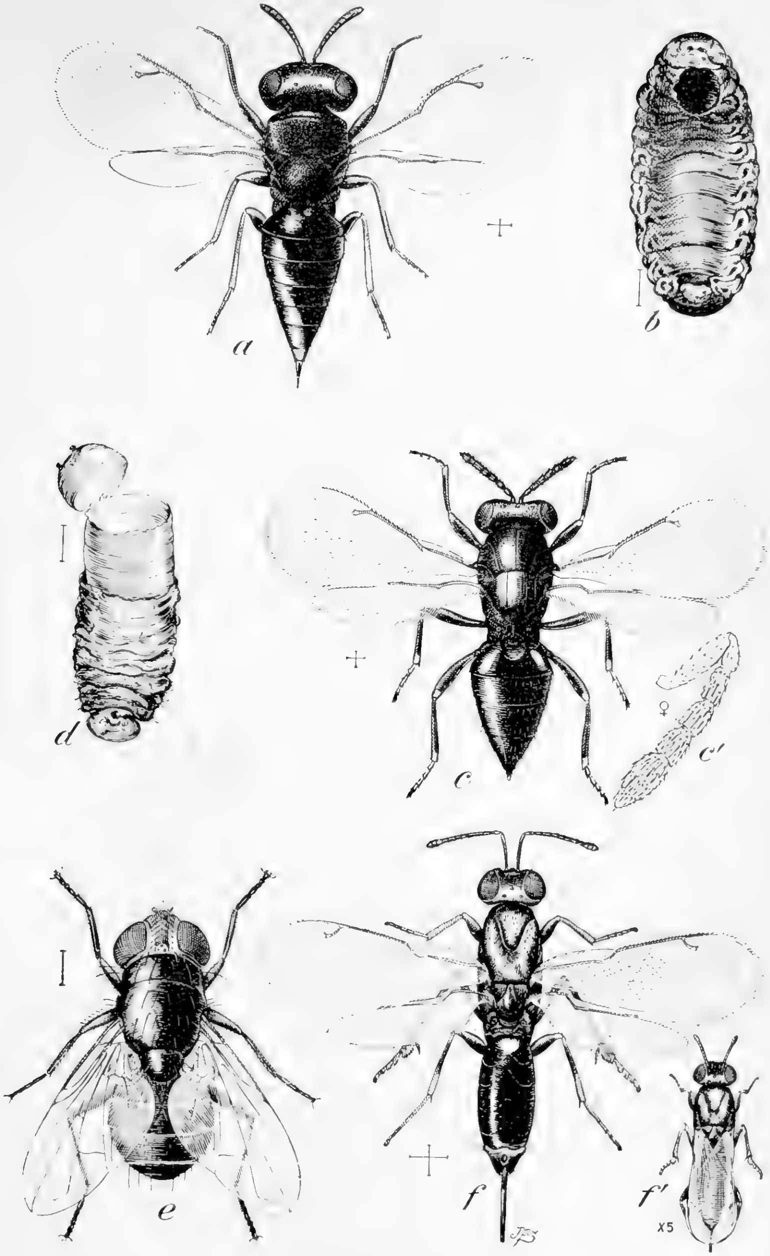
By Table LXIII we show the final summary of the records of parasitism made for a period of years to illustrate the fact that this is a factor of great importance.

TABLE LXIII.—*Parasite control of the boll weevil, by years.*

Year.	Weevil stages.	Parasites.	Mortality from parasites.
			Per cent.
1902	602	7	1.16
1903	819	59	7.20
1905, March	1,005	32	3.18
1905, August	1,702	21	1.23
1906	40,073	1,728	4.31
1907	13,602	1,121	8.24
1908	29,349	2,952	10.05
1909	11,653	620	5.32
Totals and average	98,805	6,540	6.61

Table LXIII is based upon collections of squares and bolls made throughout the infested territory under a great diversity of conditions.

The average monthly parasitic and predatory control for the years 1906 to 1909, inclusive, has been arranged below (Table LXIV) to show that insects are a factor of importance throughout the year. It should be noted especially that in the months of August and September, when the boll weevils are most numerous, from 27 to 30 per cent of the immature stages are killed by insect enemies. The average for the year of 25 per cent offers great encouragement.



BOLL-WEEVIL PARASITES.

a, *Lariophagus texanus*, female; *b*, emergence hole of *Tetrastichus hunteri* from weevil larva; *c*, *Tetrastichus hunteri*, female; *c′*, antenna of same; *d*, puparium of *Ennyomma globosa* in weevil larva; *e*, *Ennyomma globosa*; *f*, *Cerambycobius cyaniceps*, female; *f′*, natural position of same. (Original.)

TABLE LXIV.—*Weighted average insect control of immature stages of the boll weevil, by months.*

Month.	Forms examined.	Stages found.	Killed by parasites.	Percentage killed by parasites.	Killed by predators.	Percentage killed by predators.	Percentage killed by all insects.
January	5,687	1,285	54	4.20	63	4.90	9.10
February	13,597	665	56	8.42	60	9.02	17.44
March	2,500	159	2	1.25	28	17.61	18.86
May	100	56	2	3.57	0	.00	3.57
June	16,930	10,708	553	5.16	1,989	18.57	23.73
July	43,059	21,758	1,536	7.05	3,247	14.92	21.97
August	80,923	33,170	1,970	5.93	8,248	24.86	30.79
September	37,378	17,107	1,160	6.78	3,495	20.43	27.21
October	17,344	8,283	879	10.61	773	9.33	19.94
November	2,534	798	127	15.91	2	.25	16.16
December	2,663	688	82	11.91	14	2.03	13.94
Total	222,715	94,677	6,421	....	17,919	....	....
Weighted average	....	....	....	6.78	....	18.92	25.70

The weighted average insect control in June, July, August, and September proves to be 26.82 per cent and for the remainder of the year 17.11 per cent.

A few records of high insect control will suffice to illustrate the extent of control under some conditions.

TABLE LXV.—*Highest records of insect control of the boll weevil.*

Places.	Date.	Location of squares.	Stages.	Killed by insects.
				Per cent.
Athens, Tex	Aug. 1, 1907	Fallen	255	96.11
Hallettsville, Tex	Aug. 1, 1908	...do	100	92.00
Overton, Tex	Aug. 1, 1906	...do	197	85.20
Athens, Tex	Aug. 1, 1907	Hanging	75	84.00
Beeville, Tex	Aug. 1, 1906	Fallen	1,310	78.80
Victoria, Tex	July 29, 1908	...do	375	78.38
Beeville, Tex	Sept. 1, 1906	...do	678	77.40
Arlington, Tex	July —, 1909	Hanging	55	75.44
Cuero, Tex	June 20, 1908	Fallen	549	73.60

The distribution of insect control in the four principal classes of forms, and also by geographical sections, has been presented in the general discussion of natural control.

BIRDS.

Exhaustive studies of the stomachs of many birds killed in infested cotton fields by the agents of the Biological Survey of this department have emphasized the fact that the birds play a considerable part in the control of the adult boll weevils. This investigation has resulted in a list of 53 species which more or less commonly feed upon the adult weevils. In Cuba, Mr. E. A. Schwarz discovered that an oriole (*Icterus hypomelas*) has developed a habit of extracting the immature stages from the bolls and squares.

Table LXVI, which follows, is taken from Circular 64 of the Bureau of Biological Survey.

TABLE LXVI.—*Schedule of stomach examinations of birds which had eaten boll weevils.*

Species.	During January, February, and March.			During April, May, and June.			During July, August, and September.			During October, November, and December.		
	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.
Upland plover (*Bartramia longicauda*)	48	....	....	13	1	1	1	....	....	....	....	....
Killdeer (*Oxyechus vociferus*)	28	2	5	1	....	....	6	....	....	1	....	....
Quail (*Colinus virginianus*)	63	....	....	10	....	....	38	....	....	108	1	1
Nighthawk (*Chordeiles virginianus*)	....	....	....	....	....	....	10	4	15	....	....	....
Scissor-tailed flycatcher (*Muscivora forficata*)	....	....	....	....	....	....	91	5	7	....	....	....
Kingbird (*Tyrannus tyrannus*)	....	....	....	10	1	1	22	6	8	....	....	....
Crested flycatcher (*Myiarchus crinitus*)	....	....	....	7	1	2	5	1	3	....	....	....
Phœbe (*Sayornis phœbe*)	19	....	....	....	....	....	2	1	1	13	3	3
Olive-sided flycatcher (*Nuttallornis borealis*)	....	....	....	....	....	....	2	1	2	....	....	....
Alder flycatcher (*Empidonax trailli alnorum*)	....	....	....	....	....	....	3	1	2	....	....	....
Least flycatcher (*Empidonax minimus*)	....	....	....	....	....	....	14	7	21	....	....	....
Blue jay (*Cyanocitta cristata*)	8	1	1	1	....	....	1	....	....	2	....	....
Cowbird (*Molothrus ater*)	92	4	4	....	....	....	84	3	3	24	....	....
Red-winged blackbird (*Agelaius phœniceus*)	79	4	5	16	1	1	11	....	....	49	2	2
Meadowlark (*Sturnella magna*)	48	10	18	1	....	....	1	....	....	183	28	32
Western meadow lark (*Sturnella neglecta*)	52	8	11	....	....	....	....	....	....	66	12	18
Orchard oriole (*Icterus spurius*)	....	....	....	20	1	1	101	30	64	....	....	....
Baltimore oriole (*Icterus galbula*)	....	....	....	2	....	....	50	11	24	....	....	....
Bullock oriole (*Icterus bullocki*)	....	....	....	....	....	....	149	40	133	....	....	....
Rusty blackbird (*Euphagus carolinus*)	6	1	1	....	....	....	....	....	....	10	....	....
Brewer blackbird (*Euphagus cyanocephalus*)	139	24	40	1	....	....	....	....	....	5	2	2
Bronzed grackle (*Quiscalus q. æneus*)	36	5	5	19	....	....	3	....	....	3	....	....
Great-tailed grackle (*Megaquiscalus major macrourus*)	32	2	2	7	1	1	6	....	....	2	....	....
Vesper sparrow (*Poœcetes gramineus*)	29	1	1	....	....	....	....	....	....	11	....	....
Savanna sparrow (*Passerculus sandwichensis*, subspecies)	68	8	15	2	....	....	....	....	....	18	1	1
Lark sparrow (*Chondestes grammacus*)	....	....	....	13	....	....	54	1	1	....	....	....
White-throated sparrow (*Zonotrichia albicollis*)	53	1	1	4	....	....	....	....	....	9	1	1
Field sparrow (*Spizella pusilla*)	25	2	2	....	....	....	5	....	....	....	....	....
Swamp sparrow (*Melospiza georgiana*)	27	1	2	....	....	....	....	....	....	....	....	....
Fox sparrow (*Passerella iliaca*)	8	1	2	....	....	....	....	....	....	9	....	....
Towhee (*Pipilo erythrophthalmus*)	10	1	1	1	....	....	....	....	....	6	....	....
Cardinal (*Cardinalis cardinalis*)	42	....	....	7	....	....	39	3	4	....	....	....
Texan pyrrhuloxia (*Pyrrhuloxia s. texana*)	....	....	....	....	....	....	64	2	2	....	....	....
Painted bunting (*Passerina ciris*)	....	....	....	....	....	....	109	18	19	....	....	....
Dickcissel (*Spiza americana*)	....	....	....	1	....	....	26	3	3	....	....	....
Purple martin (*Progne subis*)	....	....	....	15	1	1	5	1	1	....	....	....
Cliff swallow (*Petrochelidon lunifrons*)	1	....	....	1	....	....	35	34	638	....	....	....
Barn swallow (*Hirundo erythrogastra*)	....	....	....	....	....	....	14	5	52	16	....	....
Bank swallow (*Riparia riparia*)	....	....	....	....	....	....	25	11	68	....	....	....
Loggerhead shrike (*Lanius ludovicianus*)	46	1	4	4	....	....	19	....	....	12	2	5
Yellow warbler (*Dendroica æstiva*)	....	....	....	....	....	....	25	1	1	....	....	....
Myrtle warbler (*Dendroica coronata*)	17	1	2	3	....	....	....	....	....	....	....	....
Maryland yellowthroat (*Geothlypis trichas*)	2	1	1	1	....	....	1	....	....	....	....	....
Yellow-breasted chat (*Icteria virens*)	....	....	....	....	....	....	5	1	1	....	....	....
American pipit (*Anthus pensilvanicus*)	73	34	120	....	....	....	....	....	....	8	3	4
Mockingbird (*Mimus polyglottos*)	43	2	2	13	....	....	85	5	5	5	....	....
Brown thrasher (*Toxostoma rufum*)	9	....	....	7	....	....	....	....	....	29	1	1
Carolina wren (*Thryothorus ludovicianus*)	37	6	9	31	1	2	1	....	....	7	5	6
Bewick wren (*Thryomanes bewicki*)	11	1	3	....	....	....	3	....	....	2	....	....
Winter wren (*Nannus hyemalis*)	1	1	2	....	....	....	....	....	....	....	....	....
Tufted titmouse (*Bæolophus bicolor*)	14	5	7	23	....	....	....	....	....	....	....	....
Black-crested titmouse (*Bæolophus atricristatus*)	....	....	....	....	....	....	1	....	....	2	1	1
Carolina chickadee (*Penthestes carolinensis*)	6	1	1	....	....	....	1	....	....	1	....	....

It will be noticed that the largest numbers of boll weevils were eaten during the months of July, August, and September, and also that a considerable number are consumed during the hibernating season. The most important birds are those that capture the boll weevil during the winter. According to this table these are the three species of blackbirds, two meadowlarks, six species of native sparrows, the pipit, the three species of wrens, and the two species of titmice. It will be noted that only one of the 108 quail stomachs examined showed remains of the boll weevil.

REPRESSION.

EFFECT OF BURIAL OF SQUARES AND WEEVILS.

The effect of the burial of squares and weevils is of considerable importance for the reason that some degree of burial can be practiced in the ordinary processes of cultivation. If it were to be found that the weevils could be killed by a depth of burial which could be accomplished without interference with the root system of the plants this process would be of vast importance.

At Tallulah, La., in 1910, Mr. G. D. Smith conducted an extensive series of burial experiments. The infested squares were placed in screened cages in the field. In each of these cages 2,000 infested squares were placed on October 10. A careful estimate showed that there were 250 live weevil stages for each 2,000 squares. In the first of the cages the infested squares were placed upon a sheet of wire screen 2 feet above the ground. These squares were kept constantly moist. In the second cage the squares were placed on the surface of the ground. No artificial moisture was supplied. In the third cage the squares were on the surface of the ground but were kept moist constantly. In the fourth cage the squares were buried to a depth of 2 inches and the ground was kept moist. In the fifth cage the squares were buried 4 inches and the ground was kept dry. The artificial moisture was applied three times each day during the course of the experiment. The "dry" cages were covered with canvas so that rains could not reach the squares. The soil in the locality was the typical "buckshot" of the Mississippi Delta. Immediately before the institution of the experiments several rains had made the soil moist. Observations on emergence were made from October 10 until November 15.

Table LXVII summarizes the results of these experiments.

TABLE LXVII.—*Summary of experiments in the burial of squares infested by the boll weevil at Tallulah, La., October and November, 1910.*

	Conditions.	Emergence (weevils).	Emergence.
			Per cent.
Cage 1	2 feet above surface, moist	119	47.6
Cage 2	On surface, dry	157	62.8
Cage 3	On surface, moist	147	58.8
Cage 4	Buried 2 inches, dry	62	24.8
Cage 5	Buried 2 inches, moist	6	.2
Cage 6	Buried 4 inches, dry	18	.7
Cage 7	Buried 4 inches, moist	0	.0

It will be noticed that the greatest emergence was from the two cages in which the squares were placed upon the surface of the ground. At 2 and 4 inches beneath the surface the emergence was very small. When kept dry beneath 2 inches of the soil 24 per cent of the possible emergence occurred, but at this depth when moisture was provided less than 1 per cent emerged. At a depth of 4 inches 0.7 per cent emerged in the dry cage, but none from the same depth where moisture was provided. It may be concluded from these experiments that burial beneath 2 or more inches of dry soil of the "buckshot" variety will prevent the emergence of a large portion of the weevils. If the soil is kept moist with burial at 2 inches or more below the surface the emergence is practically negligible. This is shown most clearly by comparing cages 4 and 5 in the table.

LABORATORY EXPERIMENTS IN BURIAL.

In an experiment performed at Victoria, Tex., in 1904, 1,000 infested squares were buried under from 2 to 5 inches of well-pulverized earth.[1] Seventy-five weevils emerged. Twenty-seven weevils were found which had been unable to reach the surface. Their location varied from the bottom of the receptacle to just beneath the surface. The weighted average of the distances covered by the weevils which failed to reach the surface was 2 inches.

In another series of experiments at Victoria, Tex., 74 squares were placed under wet soil. It was found that 16 per cent of the weevil stages were killed. Of the weevils which became adult 30 per cent emerged from the squares, but only 23 per cent reached the surface or escaped from an average depth of 1 inch. In these experiments, considering all the weevil stages present, 35 per cent died without escaping from the soil.

In 1904 Prof. E. D. Sanderson performed a number of burial experiments at College Station, Tex. At from 0.5 inch to 1.5 inches below the surface 26.7 per cent of the weevils emerged; at from 2 to 4 inches 4.7 per cent reached the surface.

It will be noted that these laboratory experiments substantiate the conclusion drawn from the field experiments described previously regarding the greatly increased mortality brought about by deep burial and by moisture.

BURIAL OF ADULT WEEVILS AT TIME OF HIBERNATION.

On or after November 23, 1903, at Victoria, Tex., 1,000 adult weevils were buried under from 2 to 6 inches of soil which contained from 9 to 19 per cent of water. Only five of these weevils succeeded in reaching the surface. Four of those which escaped and one which was still buried in the earth were found alive when examination was made on March 16, 1904. All the remaining weevils appear to have died where they were buried.

CONCLUSIONS FROM BURIAL EXPERIMENTS.

The field and laboratory experiments to which references have been made indicate that the boll weevil has comparatively little ability to emerge from moist soil, while dry, partially pulverized soil offers small obstacles to their emergence. The experiments also show that burial, even under moist conditions, would have to be as deep as 2 inches to bring about very decided results. The practical question therefore is whether in cotton fields the soil can be turned over to a depth of 2 inches during the growing season without injury to the crop. As is well known, one of the most important cultural methods in producing cotton is shallow cultivation. The reason for this is that the plant sends many lateral roots almost at right angles from the rows and at a very short distance beneath the surface. Many of these lateral roots lie only 2 or 3 inches beneath the ground. If they were disturbed, the plants would react by shedding the squares.

Undoubtedly the loss of fruit from this cause would more than offset any possible advantage accruing from the destruction of the

[1] Much more thoroughly pulverized than would be the case in the field.

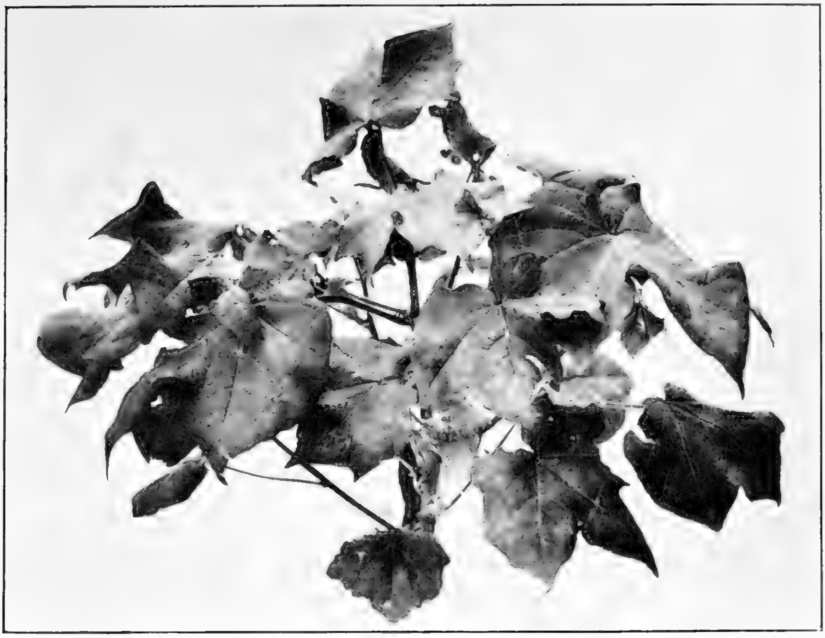


Fig. a.—Cotton before treatment with Paris green. (Original.)

Fig. b.—Cotton one week after treatment with Paris green. (Original.)

EFFECT OF PARIS GREEN ON COTTON.

weevils by burial. It is thus clear that as a means of controlling the weevil during the growing season the burial of squares is impracticable. There is a time, however, when the burial of the squares can be carried on to excellent advantage. This is in the fall when the maximum infestation has been reached. Under these conditions it makes no difference to the planter whether the lateral roots of the cotton plant are cut or not. The fruit already set on the plants will develop in either case, and any additional fruit inevitably will be destroyed by the insects. Consequently the planter may destroy many of the weevils which would mature in a short time to feed, multiply, and enter hibernation, to emerge and damage the crop of the succeeding season. In this way deep fall cultivation is a preliminary step that should be practiced in connection with the destruction of the plants. It should precede that process and should by no means be depended upon to take the place of it. After the plants have been uprooted and brought into windrows previous to burning it is advisable to plow the fields to a depth of at least 2 inches. This will result in the burial of many squares which were on the ground at the time of the uprooting or which fell during the process. The experiments show that the effectiveness of burial either before or after the uprooting of the plants will increase greatly if rains occur after the work is done. Likewise it is evident that the destruction of the weevils will be much greater in heavy soils than in lighter formations. In the Mississippi-Yazoo Delta the general nature of the soils is more or less heavy. This and the heavy precipitation in that region indicate a means of destroying the weevil that is especially important on account of the scarcity of direct means available.

INSECTICIDES.[1]

From the very beginning of the work on the boll weevil much attention has been given to testing the more promising insecticides. As one result of the offer of a $50,000 prize by the State of Texas for an efficient remedy for the boll weevil, large numbers of supposed remedies have been proposed. Doubtless the inventors have been perfectly sincere in their faith in the efficiency of these compounds. As was fully anticipated by the entomologists when the reward was offered, the commission charged with awarding the money was deluged with applications therefor, the claims in a large majority of cases being based upon some concoction supposed by the inventor to possess marvelous insecticidal properties. In comparatively few cases had the new product been tested in any way. Often samples were sent with the request that tests be made. Many of these inventions found their way to the various laboratories of this investigation, where it has been the uniform policy to give every thing of this kind a fair test and report the results to the originator. Tests were made in the field upon weevils confined by cages. This work has required a great deal of time, and the results have failed to indicate a single new compound having real value. Many of the substances tried had absolutely no effect on either plant or insect life, while others were equally fatal to both wherever they came in contact with them. The primary difficulty with all such insecticides lies in the fact that,

[1] The first two paragraphs under this heading have been modified from Bull. 51, Bureau of Entomology, p. 156.

owing to the peculiar habits and life history of the weevil, the poison can not be so applied as to reach the immature stages at all, and it can not reach the adults so as to cause sufficient mortality to result in any considerable benefit to the crop. Much work has been done in thoroughly testing the effect of Paris green. The most important results of this work have already been published in Farmers' Bulletin No. 211 of the Department of Agriculture. They will be described briefly on a subsequent page.

Among 40 other compounds tested, none proved worthy of even passing consideration for field use. As a fumigant for seed, among the eight gases or vapors tested, carbon bisulphid was found to possess considerable value when applied in the special manner described on pages 162, 163.

POWDERED ARSENATE OF LEAD.

In 1909 Messrs. Wilmon Newell and G. D. Smith, then of the Louisiana Crop Pest Commission, published the results of certain work with powdered arsenate of lead as a remedy against the boll weevil. This work was done in central Louisiana during the season of 1909. The principal experiments were located on three different plantations on plats provided for the purpose. From 1 to 10 applications were made, consisting of a total amount of poison of from 1 to 51 pounds per acre. The treated cotton yielded an average of 71 per cent more than similar cotton which was not treated. In all except one of the plats there was a net profit from the use of the poison (that is, after deducting the cost of the poison and of the labor from the value of the increased yield) of from 27 cents to $23.54 per acre. In the one exception there was a loss of $7.07 per acre.

These striking results led to extensive work on powdered arsenate of lead by the Bureau of Entomology. The services of Mr. G. D. Smith, who was directly connected with the Louisiana work to which reference has been made, were obtained. The bureau instituted numerous experiments in Louisiana, including several which duplicated the previous work in that State. This investigation has now extended through two seasons in Louisiana, and considerable work has also been done at Victoria, Tex., by Mr. J. D. Mitchell.

In the experiments of 1910, 32 plats were utilized on plantations at Livonia, Shaw, and St. Joseph, La., and Victoria, Tex. In the work in Louisiana there was a profit from the use of the poison on 20 of the plats and a loss on the 12 remaining plats. The average loss on the plats which failed to show a profit was $6.99 per acre. The average profit on the remaining plats was $5.83 per acre. Twenty-two of the 32 plats showed an increased yield of from 35 pounds to 403 pounds of seed cotton per acre. A striking result was the fact that invariably the plats upon which small amounts of the poison were applied showed profits. The work at Victoria, Tex., in 1910, consisted of four experiments. In only one of these experiments was a gain in yield obtained, and this amounted to only 59 pounds of seed cotton per acre. In all of the experiments at this place there was a loss from the application of the poison of from $1.55 to $6.52 per acre.

In 1911 the work on powdered arsenate of lead was continued. In some respects the results were contradictory of those obtained previously, but there was agreement in that profits were obtained on all

plats where small applications were made. On account of the apparent contradictions and the variations due to the seasons it is considered necessary to continue the work another season before definite conclusions as to the practical value of arsenate of lead can be drawn.

MACHINES.

FIELD MACHINERY.

Many attempts have been made to perfect machines that will assist in the warfare against the weevil. The only one of direct value that has been perfected is the chain cultivator (Pl. XX, *b;* Pl. XXI) invented by Dr. W. E. Hinds, formerly of the Bureau of Entomology, and patented by the Department of Agriculture for the benefit of the people of the United States. Its construction is based upon the discovery that the weevils in the infested squares that fall in such position as to be reached by the sun soon die. In a cotton field many of the infested squares fall within the shade of the plants, and are thus protected. The chain cultivator is designed to drag the fallen squares to the middles of the rows and leave them exposed to the sun. This it has been found to accomplish in a satisfactory manner. In fact, in tests the use of the machine has been found to result in a decided gain in production.

Although the chain cultivator was designed primarily for bringing the squares to the middles, it was found in field practice to have a most important cultural effect. The chains (so-called "log chains") are heavy enough to establish a perfect dust mulch and to destroy small weeds that may be starting. In fact, it is believed that this cultural effect would more than justify the use of the machine, regardless of the weevil. In view of the effect against the insect and the important cultural effect, it is believed that this implement or one similar to it should be used by every farmer in the weevil territory.

The chain cultivator is now regularly manufactured by one of the large dealers in farm implements, but a satisfactory machine can be made by any blacksmith. Full directions are to be found in Farmers' Bulletin 344, a copy of which may be obtained upon application to the Secretary of Agriculture.

Some forms of cultivators now in use allow the attachment of boards which drag on the ground and carry the infested squares to the middles. In fact, the principle of the chain cultivator can be incorporated in many implements now in use. It is strongly recommended that this be done for weevil control as well as for obtaining a dust mulch.

[1] Many machines have been designed to jar the weevils and infested squares from the plant and to collect them, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. The Bureau of Entomology has carefully investigated the merits of representatives of all of these classes, beginning in 1895 with a square-collecting machine that had attracted considerable local attention in Bee County, Tex. Up to the present time none of these devices has been found to be practical or to offer any definite hope of being eventually successful. At one

[1] The following three paragraphs are modified from Bull. 51, Bureau of Entomology, p. 157.

time there seemed some hope that a machine designed to pick the squares from the ground by suction might be perfected. The experiments, however, have indicated probably insurmountable difficulties; and a large implement concern, after having experimented with the matter fully, has come to the conclusion that mechanical difficulties will always prevent the perfection of such a machine.

The ultimate test of all methods or devices for controlling the weevil is to prove through a series of seasons, and under a large variety of conditions, that by their use there is produced an increase in the crop treated or protected of sufficient value to more than repay the expenses of the treatment or protection. As a general rule, where machines have been used or poisons applied, planters have provided no check upon the results obtained and have kept no close records as to the expense involved and net gain or loss resulting from the treatment. The result of such applications is, therefore, merely a general impression of gain or loss which may not agree at all with the facts.

In this connection it must be stated that all machines which assist in more satisfactory methods of preparation of the land and cultivation of the crop are of indirect advantage. This is especially the case with devices which increase the amount of work that a single hand or team of mules may do. In fact, the boll weevil has been the cause of much commendable improvement of agricultural machinery throughout the infested territory.

GINNING MACHINERY.[1]

The more important results of studies upon this class of machinery were presented in Farmers' Bulletin No. 209 of the Department of Agriculture. Modern cleaner feeders were found to be quite efficient in separating the weevils from the seed cotton, as they removed fully 70 per cent of the weevils passing into them. Of the weevils removed, over 80 per cent were still alive when taken from the trash. This fact shows the necessity for the use of some additional device which will crush or otherwise destroy all weevils taken from the cotton by the cleaner feeder. (See Pl. X, *a*.)

For the weevils escaping the action of the cleaner feeder and passing into the ginning breast with the roll there are two avenues of escape—one with the seed, the other with the motes. In these two ways it appears that over 85 per cent of the weevils passing into the gin breast escape alive, while the remainder are killed by the saws. From these facts it is evident that some way should be provided for properly caring for the motes so as to confine the weevils which are thrown out among them and secure their destruction with those removed by the cleaner feeder. Some method should also be devised for separating from the seed the weevils that pass the saws before they reach the seed house or the farmers' seed bins.

When we consider the important effect that gins have been found to possess in spreading the weevil, especially near the border line of infestation, it appears exceedingly desirable that improvements in gin machinery should be made in the following particulars:

First. The area and distance through which the action of the picker roll in the cleaner feeder is continued should be considerably increased,

[1] This section is modified from Bull. 51, Bureau of Entomology, pp. 158, 159.

Fig. a.—Early fall destruction of stalks, the fundamental method for controlling the boll weevil. Windrowing stalks for burning. (Original.)

Fig. b.—Chain cultivator passing through cotton rows. (Original.)

CULTURAL CONTROL OF THE BOLL WEEVIL.

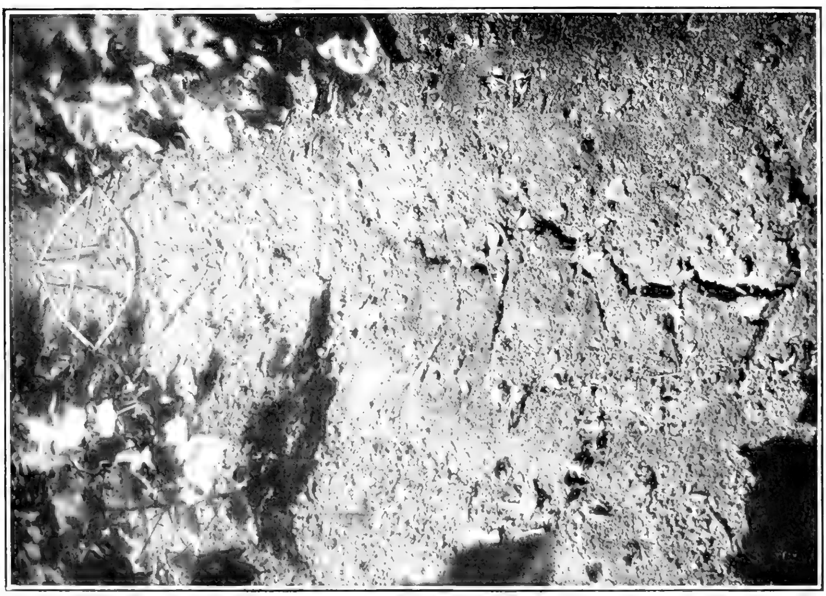


Fig. a.—Space between cotton rows before passage of cultivator. (Original.)

Fig. b.—Effect after passage of cultivator. (Original.)

USE OF CHAIN CULTIVATOR.

compression rollers or some other device being employed to destroy the weevils separated by the cleaner.

Second. Some method should be devised for keeping under control the weevils escaping alive with the motes, as under present conditions they have free range through the ginnery.

Third. Possibly the most important of the devices needed is an apparatus which may be applied near the gin (possibly as the seeds leave the gin breast and drop into the seed chute) by which the weevils may be separated from the seed and brought under control, so that they may be destroyed.

With these improvements the oil mills would almost cease to be a factor in the dissemination of weevils, and the movement of seed, either for planting, stock feeding, or fertilizer, would practically cease to be what it is at present, a factor in the spread of the weevil.

FUTILE METHODS WHICH HAVE BEEN SUGGESTED.[1]

MINERAL PAINT AND COTTONSEED OIL.

The very serious nature of the boll-weevil problem is constantly illustrated by the manner in which various useless devices and nostrums are brought to public attention. At one time it was widely alleged that mineral paint would act as a specific against the weevil. An equally fallacious theory that also received considerable popular attention was to the effect that cottonseed meal exerted a powerful attraction for the pest.

SPRAYING.

Probably the most important useless recommendation has been that of spraying. It was supposed for some time by certain parties that it might be possible to poison weevils economically by attracting them to some sweetened preparation. The experiments conducted to determine the attraction of various sweetened substances demonstrate the fallacy of the theory. Even if these substances exerted as much attraction as was supposed, there would be insurmountable difficulties in the application of the method in the field. It is true that it is possible to destroy a certain number of weevils in regions where stubble cotton occurs by heavily spraying the earliest plants, but this method is of immeasurably less importance than the simple practice of cultural methods.

SULPHUR.

The old idea, the fallacy of which has been explained repeatedly by economic entomologists for the past 50 years, namely, that sulphur can be forced into the system of the plants to make them immune to insect attack, sometimes crops out with reference to the boll weevil. It is scarcely necessary to call attention to the fallacy of attempting to destroy the boll weevil by soaking the seed in chemicals with the hope of making the plants that are to grow from them distasteful or poisonous to the insect. Any money expended by the farmer in following this absurd practice is entirely wasted.

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[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 159, 160.

PARIS GREEN.

One of the most important fallacies regarding a remedy for the boll weevil was that which received great attention during the season of 1904, namely, that Paris green is a specific for the pest. The urgent demand for a specific was evidenced by the very extensive use of this substance. A portion of the great attention that it received publicly was due to the fact that early in the season a certain number of weevils may be killed by it. Applications made by spraying are even less effective than dusting with the dry Paris green. As was pointed out in Farmers' Bulletin No. 211, which deals with exhaustive field and laboratory experiments with Paris green, the number so destroyed in the spring really means nothing whatever to the crop later in the season when the plants have put on squares and the poison is no longer effective. As a matter of fact, the uselessness of Paris green was quickly discovered by planters. Since 1904 practically none has been used in the warfare against the pest. (See Pl. XIX.)

TRAPPING AT LIGHT.

There is still, in many quarters in Texas and Louisiana, a supposition that it is possible to attract the boll weevil to lights. A number of machines have been constructed based upon this idea. Whether or not the boll weevil can be attracted to lights was one of the first matters that was investigated by entomologists. During September, 1897, Mr. J. D. Mitchell, of Victoria, Tex., a naturalist and cotton planter, set out trap lanterns in a cotton field in Victoria for one night, and sent the insects captured to this bureau for examination. In all, 24,492 specimens were taken, representing approximately 328 species. Divided according to habit, whether injurious or beneficial, the result was: Injurious species, 13,113 specimens; beneficial species, 8,262 specimens; of a negative character, 3,117. The interesting point in connection with this experiment was the fact that not a single specimen of the boll weevil was found, although the lights were placed in the midst of fields where the insects were very abundant. Since that time other investigators have looked into this matter fully. Lights have been kept burning in cotton fields night after night for several weeks. In no case has a single specimen of the boll weevil been discovered, although thousands of species of insects have been captured.

The popular misapprehension about the possibility of capturing the boll weevil at lights is due to the fact that somewhat similar insects, *Balaninus victoriensis*, and other acorn weevils, differ from the boll weevil in that lights exert a strong attraction for them. During occasional seasons the acorn weevils are exceedingly common in Texas, and great numbers of them fly to the electric lights.

OTHER PROPOSED REMEDIES.

Hundreds of proposed remedies, in addition to those which have been mentioned, have been carefully investigated. The claims of their advocates in practically all cases are based upon faulty observations or careless experiments. The strong tendency of the weevil to die in confinement, which has been referred to, has caused many

honest persons to suppose that the substances they are applying have killed it. Moreover, an insuperable difficulty that these special preparations have encountered is the impracticability of the application in the field. Hundreds of known substances will kill the weevil when brought into contact with it. The difficulty is to apply them in an economical way in the field. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

REQUIREMENTS OF A SATISFACTORY METHOD OF BOLL-WEEVIL CONTROL.[1]

The difficulties in the way of controlling the boll weevil lie both in its habits and manner of work and also in the peculiar industrial conditions involved in the production of the staple in the Southern States. The facts that in all stages, except the imago, the weevil lives within the fruit of the plant, well protected from any poisons that might be applied, and in that stage takes food normally only by inserting its snout within the substance of the plant; that it frequently requires only 12 days for development from egg to adult, and the progeny of a single pair in a season may exceed 3,000,000 individuals; that it adapts itself to climatic conditions to the extent that the egg stage alone in November may occupy as much time as all the immature stages together in July or August, are factors that combine to make it one of the most difficult insects to control. It is, consequently, natural that all the investigations of the Bureau of Entomology have pointed toward the prime importance of methods of control which involve no outlay for materials and very little for labor. Methods which involve some direct financial outlay for material or machinery are not in accord with labor conditions surrounding cotton production in the United States. Moreover, the indirect methods advocated are in keeping with the general tendency of cotton culture; that is, to procure an early crop, and at the same time have the great advantage of avoiding damage by a large number of other destructive insects, especially the bollworm. Nevertheless it must not be understood that attention has not been paid to the investigation of means looking toward the direct extermination of the pest. Much work has been done, but the results have all been negative.

BASIS FOR MEANS OF REPRESSION.

In spite of the many difficulties involved in the control of the boll weevil certain generally satisfactory means of repression are at hand. They consist of both direct and indirect means. Those of an indirect nature are designed to increase the advantage gained by the direct measures and to increase the effectiveness of the several natural factors which serve to reduce the number of weevils. Thus, the control measures constitute a combination of expedients, the parts of which interact in many ways. Naturally, the best results are obtained when the planter can put into practice all of the essential parts of the combination.

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[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 160, 161.

It is obvious that any method of controlling the boll weevil must depend upon full knowledge regarding its life history and the natural forces which tend to prevent its multiplication. Certain practices which upon superficial observation might be considered important in the control of the insect upon investigation may be found to be of no avail whatever. In fact, in some cases what appear to be feasible means of control are worse than useless, because they tend to nullify the effects of natural forces which act against the weevil. This is notably the case with the practice of attaching a bar to a cultivator to jar the infested squares from the plants. As will be explained later, this practice is of advantage only under very restricted conditions. Throughout the greater part of the infested territory it is an assistance rather than a hindrance to the boll weevil.

There are seven features of the life history of the weevil that are of cardinal importance in control. These are indicated below.

1. The weevil has no food plant but cotton.
2. The mortality of the weevil during the winter is very high.
3. The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.
4. Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the summer months.
5. The drying of the infested squares, as the result of heat, soon destroys the immature stages of the weevil contained therein.
6. The weevil is attacked by many different species of insect enemies, the effectiveness of which is increased by certain practices.
7. The weevil has but little ability to emerge when buried under wet soil.

Exactly how each of these features of the life history of the weevil affects plans for practical control will be explained in the following paragraphs.

In the case of many of the important injurious insects the problem of control is greatly complicated by the fact that the pests can subsist upon more than one food plant. In some cases a single species attacks several cultivated crops. In other cases the pests can subsist upon native plants practically as well as upon the cultivated species. All these difficulties are absent in the case of the boll-weevil problem. As has been shown in the preceding pages, the insect is absolutely restricted to the cotton plant for food and for opportunities for breeding. The problem is therefore much more simple than it would be if the weevil could subsist upon any other plant in the absence of cotton. This peculiarity of the weevil was the basis of the recommendation made in 1894 that the pest be exterminated absolutely in the United States by the abandonment of cotton. At that time only a few counties in Texas were affected. The procedure would have involved small expense. Even now the weevil could be exterminated in a single season by preventing the planting of cotton and the growth of volunteer plants. This proposal has been made at various times, notably at the national boll-weevil convention held in Shreveport, La., in 1906.

Various difficulties, however, appear to render the plan entirely impracticable. In the first place, there would be strong opposition in large regions in Texas where the planters have learned to combat

the weevil successfully. This opposition would undoubtedly be sufficiently strong to prevent cooperation in a large territory. Moreover, the expense would be enormous. A large army of inspectors would be required. The work would not end with the prevention of planting cotton, but would necessarily extend to the destruction of volunteer plants which would be found along roads, railroads, about gins and oil mills, and on plantations throughout the infested region. The loss to mills, railroads, merchants, banks, and others dependent upon the cotton trade would complicate matters further. Unless a plan of reimbursement were followed there would be strenuous opposition from these quarters, and any scheme of payment for damages would increase the cost still further. From a theoretical standpoint all the expenses involved would be justified. The saving in a few years would more than offset the cost. Nevertheless, the practical difficulties undoubtedly will always prevent the execution of the plan. All interests now seem to favor the necessary adjustment of conditions to the boll weevil rather than total eradication—once practicable but now little more than visionary.

Under the discussion of the hibernation of the weevil it was shown that during the several years in which careful experiments have been performed the average rate of survival was 7.6 per cent. It is noteworthy that frequently the survival is much smaller. In the experiments to which reference has been made it ranged from 0.5 per cent to 20 per cent. The most important means of controlling the boll weevil that are available are designed to increase the tremendous mortality caused by natural conditions during the winter. The destruction of any certain number of weevils during the winter is much more important than the destruction of much larger numbers at any other season. The best means at the command of the farmer for increasing the winter mortality is through the uprooting and burning or burial of the stalks at an early date in the fall. (See Pl. XX, *a*.) Numerous experiments have shown the lessened mortality due to depriving the weevils of their food at early dates in the autumn. In fact, the experiments showed a practically uniform increase in the number of weevils surviving as the dates of the destruction of the plants became later. For instance, in all of the experiments performed in Texas it was found that destruction in September resulted in a survival of only 0.2 per cent; destruction two weeks later showed a survival of 2.3 per cent; destruction during the last half of October, 5.6 per cent; and during the first half of November, 15.4 per cent. The results of the Louisiana experiments were similar. Destruction in September showed a survival of 0.3 per cent; destruction in the first half of October, 2 per cent; in the last half of October, 8 per cent.

In addition to the experiments in which the weevils have been placed in cages at different times in the fall, the Bureau of Entomology has conducted considerable field work to show the benefits of fall destruction. The most striking experiment was performed at Calhoun County, Tex., in 1906. In this experiment an isolated area of over 400 acres of cotton was utilized. There was no other cotton within a distance of 15 miles. By contracts entered into by the department, the farmers uprooted and burned all of the stalks during the first 10 days in October, and provision was made to prevent

the growing of sprout cotton. As a check against this area, cotton lands about 30 miles away were used. Here the stalks were not destroyed in the fall, and the interpretation of the results of the experiment was based upon a comparison of the number of weevils present during the following season in the two localities. In May following the destruction of the plants careful search revealed only one weevil in the experimental area. In the check, however, the weevils were so numerous at this time that practically all of the squares had been destroyed. Examinations made later showed similar advantage in regard to freedom from the boll weevil of the area where the stalks were destroyed in October. The last examination was made on August 20. At this time there were 10 sound bolls to the plant on the experimental area and only 3 to the plant in the check area. The difference in yield between the two areas was about 600 pounds of seed cotton per acre. The work, therefore, resulted in an advantage amounting to about $18 per acre.

Newell and Dougherty[1] have described a very satisfactory device for cutting the cotton stalks in the fall. It consists of a triangular wooden framework, designed to pass between the rows and cut two at the same time. In the process of cutting, the machine windrows the stalks from two rows into the middle between the rows. The runners are provided with knives made of sharpened metal. Old saws have been found well adapted to the purpose. It is important to provide a metal runner at the rear end of the machine to prevent sliding. This runner is designed to run an inch or more beneath the surface of the ground. The device can be made by any blacksmith at a cost of about $4. It will cut and windrow from 10 to 15 acres of stalks in a day.

There is a disadvantage in cutting the stalks at or near the surface of the ground: If warm weather follows, many of the roots will give rise to sprouts that will furnish the weevils food. On this account the process is less effective than uprooting the plants. Wherever the stalk cutter is used, it should be followed by plows to remove the roots from the ground.

There is another important means by which the winter mortality of the weevil may be increased. This is by removing the hibernating quarters or destroying them after the weevil has gone into hibernation. Many of the insects are to be found in the winter in trash and débris found in and about cotton fields. The more shelter there is provided in the form of weeds growing about the fields, the more favorable the conditions will be for the insect. By the burning of such hibernating quarters as are found in the cotton fields and in their immediate vicinity a farmer can cut off a very large proportion of the weevils that would otherwise emerge to damage the crop.

The prolonged period of emergence from hibernation gives the planter another important advantage over the weevil. It has been shown on preceding pages that the period of emergence from hibernation extends, in normal seasons, to practically the 1st of July. In fact, except in one of the experiments that was performed, the last weevils did not appear until after the 20th of June. In the one exception the last weevils appeared on the 6th of June. In Texas it was found that 75 per cent of the emerging weevils appeared after

[1] Cir. 30, Louisiana Crop Pest Commission.

April 8 and in Louisiana 64 per cent. In Texas, after May 1, in all the experiments, from 4 to 18 per cent of the surviving weevils appeared. In Louisiana, after May 1, from 30 to 40 per cent emerged.

It is obvious that the fact that many weevils do not appear until long after cotton can be planted and brought to a fruiting stage is a very great advantage to the planter. A portion of a crop at least can be set before the weevils have become active. Usually it is possible to plant a crop sufficiently early to have it set some fruit before much more than 50 per cent of the surviving weevils have emerged.

Attention was directed to the fact that the development of the weevil is much slower in the early portion of the season than later. For instance, at Vicksburg, Miss., the average period of development in April is 30 days and in May 19 days. In June the period is shortened to 15 days. Consequently the planter has an opportunity to force the development of fruit on the plants when the weevils are being held in check by the temperatures of the spring months. The ability of the cotton plant to grow during April and May is much greater than that of the weevils. This gives a margin of which the planter can take advantage.

In the section dealing with natural control it was shown that climatic checks are the most important that the boll weevil experiences. The principal manner in which climatic factors affect the weevil is through the drying of the fruit. Naturally, the more heat and light there is to reach the fallen squares, the greater will be the effectiveness of the most important natural means of control. This is the basis for the recommendation that the plants should be given considerable space, not only between the rows, but in the drill. Of course, it would be possible to place the plants entirely too far apart, and thus reduce the yield. There is a happy medium, however, at which planters must arrive from experience on their individual places. At the same time, varieties should be cultivated which have a minimum tendency toward the formation of leafage.

The work of the insect enemies of the boll weevil is increasing from year to year. This work should be encouraged in so far as possible. It happens that several of the recommendations made for other reasons will result in facilitating the work of the enemies of the weevil. This is the case with early planting, wide spacing, and the use of varieties with sparse rather than dense leafage. Even fall destruction is not a disadvantage, because it forces the parasites at the active season to native hosts that carry them through the winter. Wherever possible, varieties should be planted which retain a large proportion of the infested squares, because the hanging squares are more favorable for parasite attack than those which fall.

Whenever the squares are picked by hand they should not be burned or buried, but placed in screened cages. In this way the weevils will be destroyed while the parasites may escape.

Numerous experiments have shown that a large proportion of the weevils buried under 2 inches of moist soil can not reach the surface. Unfortunately, it is not possible to plow the infested squares under 2 inches of soil during the growing season. The operation would result in injury to the root system and cause great shedding. Nevertheless it is possible for the planter to follow this practice after maximum infestation has been reached and after the plants have

been uprooted. Therefore, every means should be taken at the time of maximum infestation to plow under the infested squares as deeply as possible. This method is of little use in dry regions, but fortunately is of great importance in humid regions where other means of control are comparatively lacking in efficiency. It is also assisted greatly by the occurrence of large areas of so-called stiff soils in the humid area.

SUMMARY OF MEANS OF REPRESSION OF THE BOLL WEEVIL.

In the preceding pages all effective methods of controlling the boll weevil have been described in a general way, and their connection with the life history of the insect shown. Further details regarding the application of the methods have been published in Farmers' Bulletin 344. In the present connection it will be sufficient to summarize the subject. The following are the essential features of the control of the boll weevil:

1. *Prevention of the invasion of new territory by means of quarantines directed against farm commodities that are likely to carry the weevil.* It is not necessary to have a quarantine applied to an extended list of articles. Only a few forms of cotton and of cotton by-products need to be considered. The most important is seed cotton. Next in importance are cottonseed and cottonseed hulls. There is no danger in cottonseed meal and scarcely any appreciable danger in baled cotton.

Cottonseed can be easily rendered entirely safe by fumigation with carbon bisulphid, as described in this bulletin.

2. *The destruction of the weevils in the fall by uprooting and burning or burying the plants.* This is by far the most important step in control. (See Pl. XX, *a*.) It is so important that unless it is followed all other means will avail little to the planter.

The burning of the cotton plants is, of course, a bad agricultural practice. It should not be followed except in extreme emergencies. In all other cases the plants should be uprooted as soon as the cotton can be picked and cut by means of stalk choppers and immediately plowed beneath the surface. The ground should afterwards be harrowed or dragged to make it still more difficult for the insects to emerge.

In many cases it will be found inadvisable to wait for the uprooting of the plants until all of the cotton is picked. After only a small portion remains for the pickers, it is entirely feasible to uproot the plants by means of a turning plow and leave them in the field so that the cotton can be picked. This will hasten the opening of the green bolls and frequently result in a considerable saving to the planter.

3. *The destruction of the weevils during the winter.* This is accomplished by the destruction of the places in which the insects hibernate. Many such places are found in the cotton fields or in their immediate vicinity. A certain number of the weevils will of course make their way into the heavy woods and other situations beyond the reach of of the planter, but many remain where they can be reached.

4. *Obtaining an early crop.* (See Pl. XXII.) The importance of obtaining an early crop has been shown to depend upon the small number of weevils which hibernate successfully, their late emergence from hibernating quarters, and their comparatively slow development

Fig. a.—Late-planted cotton under boll-weevil conditions, given same culture as early planting. (Original.)

Fig. b.—Early-planted cotton adjoining the late planting under same conditions. (Original.)

RESULTS OF EARLY AND LATE PLANTING OF COTTON.

during the early part of the season. The obtaining of an early crop is brought about by early preparation of the soil, by early planting, by the use of early-maturing varieties, by a system of fertilization which will stimulate the growth of the plants, and by continuous shallow cultivation during the season.

5. *Increasing the effects of climatic control.* As has been shown, practically 50 per cent of all the weevil stages throughout the infested territory are destroyed by climatic influences. This means that the power of reproduction of the weevils is reduced by one-half. A planter can increase the advantage in his favor by providing a suitable distance between the plants and between the rows. It is also important to use varieties, where possible, which have a comparatively small leaf area. The use of the chain cultivator will be found of great value in connection with obtaining the full effects of climatic control.

6. *Encouraging the insect enemies of the weevil.* This is accomplished in part by procedures already recommended and further by the use of varieties which have a well-developed tendency to retain the fruit and which also have a comparatively open structure and small leafage.

7. *Hand picking of weevils and squares.* This is a practice of little general importance. Although under some local conditions it may be highly advisable, everything depends upon the cheapness with which the work can be done. On crops produced by wage hands it is doubtful if the hand picking of the weevils or squares will ever result in any profit. Where the crop is produced on the share basis, and the acreage is sufficiently small to allow considerable work in the picking of the squares, the practice will undoubtedly pay. It is, therefore, a matter that must be taken into consideration by each individual planter. It can not be recommended generally, for the reason that under many conditions it would result in loss.

Wherever square picking is practiced the squares should not be burned. They should be placed in cages, so that the parasites may escape and continue their work. As a matter of fact, under most conditions it is likely that the encouragement that can be given the parasites by this means is of much more importance than any direct checking of the weevil by the process of hand picking. Wherever squares are burned the planter is merely destroying the enemies of the weevil and consequently working against his own interest.

8. *Control at gins.*—The use of modern cleaner feeders will eliminate practically all of the weevils from cottonseed. Such devices should be used at least in the case of all seed that is intended for shipment into any infested localities and especially along the outer border of the infested territory, where wagons may carry infested cottonseed some distance into territory that has not been reached by the weevil. It is important in connection with the cleaner feeders to provide some means for the destruction of the insects that are captured. In some cases where the cleaner feeders are in operation the discharge is allowed to accumulate in an open barrel or box. From such receptacles weevils readily make their way into the seed cotton in storage. It is a simple matter to provide compression rollers through which the discharge from the cleaner feeder is passed. If, for any reason, the use of compression rollers is impracticable, the trash should be

fumigated at frequent intervals by means of carbon bisulphid or collected in a closed chamber and burned before the weevils have an opportunity to escape. (See Pl. X, *a*.)

9. *Fumigation of seed* (fig. 34). This is a means of repression that will be of avail only in the case of shipments of seed into uninfested territory. It has been found that carbon bisulphid is the most satisfactory agent to use. Great care should be taken to insure thoroughness of application.

The use of a crossbar attached to the cultivator to jar the infested squares from the plants has frequently been recommended. Under some conditions this practice should be followed, but under others it is worse than futile. It was shown, in the treatment of the subject of natural control of the weevil, that in the humid region, including Arkansas, Louisiana, and the eastern portion of Texas, the mortality in hanging squares is greater than in fallen squares. For this reason it is better for the squares to remain on the plants. There is another reason why they should be allowed to remain on the plants which applies especially to the moist region in which the boll weevil is now doing great damage. This is, that the hanging squares are much preferred by the boll-weevil parasites. The records have invariably shown a higher rate of parasitism in hanging squares than in fallen squares. In this way the hanging squares furnish a means for the breeding of parasites, thereby enabling them to establish themselves in the field.

It will be noted that the means of repression of the boll weevil may be divided into two classes, namely, direct and indirect.

The direct means of control are the destruction of the weevils in the fall by destroying the plants and burning or burying the immature stages, hand picking of weevils and squares under some conditions, the burial of the infested forms at the time of maximum infestation, and the burning of the hibernating weevils in their winter quarters.

The indirect means of control are early planting, the use of early varieties and of fertilizers that will accelerate growth, the selection of fields where the soil is suitable to rapid development, frequent shallow cultivation, the encouragement of the parasites of the weevil by placing the infested squares that may be picked by hand in cages instead of burning them, and the use of machinery which facilitates the various operations in preparing the land and cultivating the crop. These have the effect of increasing the acreage that a hand may cultivate. In view of the fact that the boll weevil forces a reduction in the acreage per hand, this is a consideration of some moment.

DESTROYING THE BOLL WEEVIL IN COTTON SEED.

It has been shown in this bulletin that adult weevils are frequently to be found in cotton seed and that there is danger in the dissemination of the pest through the shipment of the seed. A number of experiments have been performed to discover means of killing the weevils found in seed. There are great difficulties to be overcome on account of the density of the seed and its practical impenetrability by certain fumigants. It was shown, for instance, that hydrocyanic-acid gas has practically no penetrating power whatever. Carbon bisulphid was found to be satisfactory, although a special apparatus and special manipulation of the seed are necessary to insure

success. The method described below, from Farmers' Bulletin 209, is that which has been used by the bureau in cases where it has been necessary to free cotton seed of the weevils.

The following plan for this work is proposed: A tight matched-board box should be provided having sides 4 feet high, open on top, and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon bisulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 34) will give an idea of this apparatus. It should consist of three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at a_1 regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle fitted at b^1 with a tight stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, b_2, reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, b_4, reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. *C* is a piece of ordinary $\frac{3}{8}$-inch iron gas pipe about $3\frac{1}{2}$ feet long, but this may be any desired length. It is closed and roundly pointed at the tip, and for about 15 to 18 inches of its length provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

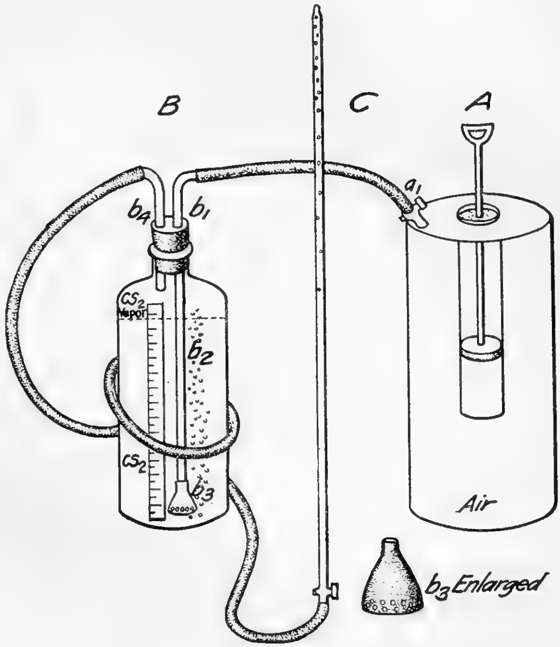

FIG. 34.—Apparatus for fumigating cotton seed in the sack. (After Hunter.)

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the bisulphid, and the couplings will have to be frequently replaced. This, however, will not be a considerable item of expense. With the apparatus just described one operator would be able to accomplish the entire work of disinfection. The amount of carbon bisulphid recommended is about 1 ounce for each 3-bushel sack. It is safe to say that this can be secured for less than 1 cent per ounce when purchased in 25 or 50 pound lots, making the cost of bisulphid not over 1 cent per sack. As it requires but from two to three minutes to vaporize 1 ounce of the liquid in the manner described, the expense for labor in application would not amount to one-half a cent per sack. Fumigation with carbon bisulphid can therefore be effectively made at the slight expense of from 1 to $1\frac{1}{2}$ cents per 100-pound sack.

Application of the bisulphid in this manner reduces the elements of danger to a minimum, as the vapor is almost wholly confined and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of bisulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for forty hours after the gas is injected.

LEGAL RESTRICTIONS REGARDING THE BOLL WEEVIL.

UNITED STATES STATUTE.

The statute, quoted in part below, prohibits the interstate shipment of the boll weevil and certain other insects, and provides penalties:

AN ACT To prohibit the importation or interstate transportation of insect pests, and the use of the United States mails for that purpose.

That no railroad, steamboat, express, stage, or other transportation company shall knowingly transport from one State or Territory into any other State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, or from a foreign country into the United States, the * * * boll weevil, in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid, except when shipped for scientific purposes under the regulations hereinafter provided for, nor shall any person remove from one State or Territory into another State or Territory, or from a foreign country into the United States, or from a State or Territory into the District of Columbia, or from the District of Columbia into any State or Territory, except for scientific purposes under the regulations hereinafter provided for, the * * * boll weevil, * * * in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid. (33 Stat. L., 1269.)

Sec. 2. That any letter, parcel, box, or other package containing the * * * boll weevil * * * in a live state or other insect in a live state which is notoriously injurious to cultivated crops; * * * or any letter, parcel, box, or package which contains the eggs, pupæ or larvæ of any insect injurious as aforesaid, whether sealed as first class matter or not, is hereby declared to be nonmailable matter, except when mailed for scientific purposes under the regulations hereinafter provided for, and shall not be conveyed in the mails, nor delivered from any post office, nor by any letter carrier, except when mailed for scientific purposes under the regulations hereinafter provided for; and any person who shall knowingly deposit, or cause to be deposited, for mailing or delivery, anything declared by this section to be nonmailable matter, or cause to be taken from the mails for the purpose of retaining, circulating, or disposing of, or of aiding in the retention, circulation or disposition of the same shall, for each and every offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court: *Provided*, That nothing in this Act shall authorize any person to open any letter or sealed matter of the first class not addressed to himself. (33 Stat. L., 1270.)

Sec. 3. That it shall be the duty of the Secretary of Agriculture and he is hereby authorized and directed to prepare and promulgate rules and regulations under which the insects covered by sections one and two of this Act may be mailed, shipped, transported, delivered and removed, for scientific purposes, from one State or Territory into another State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, and any insects covered by sections one and two of this Act may be so mailed, shipped, transported, delivered and removed, for scientific purposes, under the rules and regulations of the Secretary of Agriculture: *Provided*, That the rules and regulations of the Secretary of Agriculture, in so far as they affect the method of mailing insects, shall be approved by the Postmaster-General, and nothing in this Act shall be construed to prevent any State from making and enforcing laws in furtherance of the purposes of this Act, prohibiting or regulating the admission into that State of insects from a foreign country. (33 Stat. L., 1270.)

Sec. 4. That any person, company, or corporation who shall knowingly violate the provisions of section one of this Act shall, for each offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court. (33 Stat. L., 1270.)

QUARANTINES OF THE SEVERAL STATES.

Quarantines designed to prevent the importation of the boll weevil are now in force in the following States and Territories: Alabama, California, Georgia, Louisiana, Mississippi, North Carolina, Okla-

homa, Porto Rico, South Carolina, Tennessee, and Texas. They are directed against all infested counties and States, as well as against all counties which may become infested in the future. The following pages give the substance of the present restrictions. For further particulars the quarantine officers of the several States should be addressed directly.

Alabama.—The present quarantine regulations in Alabama were promulgated by the Alabama State board of horticulture on April 4, 1911. The quarantine applies to cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which had been used), cotton-pickers' sacks, and corn in the shuck. Importation of these articles into uninfested territory from infested territory, or from any point situated within 20 miles of the area known to be infested, is prohibited. However, between January 15 and July 15 shipments of these articles originating within or ginned within a zone 20 miles in length immediately adjoining the infested territory may be made to points not more than 40 miles outside of the line of infestation. Between October 1 and June 30 shipments of Spanish moss, baled or unbaled, originating in infested territory, are prohibited from entering or passing through uninfested parts of the State. Cotton lint (loose, baled, flat, or compressed) originating in infested localities is prohibited except during the months of June, July, and August. The shipment of household goods is prohibited unless accompanied by an affidavit attached to the waybill to the effect that the shipment contains no cotton, cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, corn in the shuck, or loose Spanish moss, except that in shipments of household goods made during the months of July, August, and September corn shucks or Spanish moss may be used for packing. All shipments of quarantined articles must be made in tightly closed box cars. No person except the entomologist of the State board of horticulture and his deputies is allowed to have in possession outside of the weevil-infested territory any live stages of the boll weevil. The penalty provided is a fine of from $100 to $500.

California.—In California the boll-weevil quarantine is in the form of an order issued by the State commissioner of agriculture on April 23, 1908.. This provides that all cotton seed shipped into California shall be consigned through one of the State deputy commissioners of horticulture. These shipments shall be fumigated with carbon bisulphid for a period of 24 hours by a deputy commissioner. Deputy commissioners are located at El Centro, San Bernardino, Riverside, Los Angeles, and San Diego.

Florida.—The restrictions in effect are authorized by a statute passed in 1911 which established the office of inspector of nursery stock. Dr. E. W. Berger, Gainesville, is the present inspector.

Georgia.—Previous to August 15, 1904, the Georgia State board of entomology had authority, by virtue of the legislative act which created it, to enact such regulations as it deemed necessary to prevent the introduction or dissemination of injurious crop pests or diseases. On August 28, 1903, this board adopted a regulation prohibiting the introduction of cotton seed from Texas except under a certificate from an authorized State or Government entomologist stating that the seed had been fumigated in such manner as to kill any stage of boll weevils which might be contained therein. On

August 15, 1904, an act of the General Assembly of the State of Georgia was approved, but further amended August 23, 1905, whereby cotton seed, seed cotton, cottonseed hulls, or cotton lint in bales or loose, corn in the husk, or all material, including household goods packed in any of the above quarantined products, are prohibited from being brought into the State except when there is attached thereto a certificate signed by an authorized State or Government entomologist to the effect that said material was grown in and was shipped from a point where, by actual inspection, the Mexican cotton-boll weevil was not found to exist. Through shipments of quarantined articles may be made in cars which must be tightly closed, and no unloading is allowed during transit through the State. No common carrier shall use for bedding or feed for live stock any of the quarantined articles when the shipments originate in regions infested with the boll weevil.

Mr. E. L. Worsham, capitol, Atlanta, is the present quarantine official in Georgia.

Louisiana.—The State entomologist of Louisiana is, by a law passed December 15, 1903, empowered to quarantine against the cotton-boll weevil whenever it seems advisable. At present the State is entirely infested, but if in the future portions of the State should be freed the entomologist is fully empowered to restrict dangerous shipments into such portions.

Mr. J. B. Garrett, Baton Rouge, La., is the quarantine officer of this State.

Mississippi.—The State legislature in 1908 passed a law giving the entomologist of the experiment station considerable authority in regard to the quarantines against the boll weevil. As only part of the State is infested, and it may be possible to save certain portions several years of injury, the rules established in 1904 should be considered in force as restricting shipments into uninfested counties. An absolute quarantine is established against cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which have been used), cotton-pickers' sacks, corn in the shuck, unsacked corn, unsacked oats, unsacked wheat, and unsacked cowpeas from the infested territory. Through shipments of quarantined articles must be in tightly closed cars, which must not be unloaded while in transit through the State. Household goods to be shipped from infested territory into uninfested parts of the State of Mississippi must be accompanied by an affidavit to the effect that no quarantined articles are contained as packing or otherwise in the shipment. Baled cotton can be shipped into the uninfested parts of the State only in tightly closed cars.

Prof. R. W. Harned, Agricultural College, Miss., is the quarantine officer of this State.

North Carolina.—By virtue of authority from the State legislature to prevent the importation of crop pests, the North Carolina Crop Pest Commission early in 1904 adopted rules establishing a quarantine against all localities where the Mexican cotton-boll weevil is known to exist. The quarantine was absolute and applied to cotton, cotton seed, cottonseed meal, cottonseed hulls, hay, oats, corn, rice, straw, rice chaff, and other grain or material likely to harbor any stage of the boll weevil.

The rules published in July, 1910, are reproduced verbatim:

REGULATION No. 15. No transportation company, common carrier, or agent thereof, shall bring into North Carolina any shipment of seed cotton or cotton-seed hulls originating at any point in the States of Texas, Louisiana, Mississippi, Oklahoma and Alabama. And this shall likewise apply to other States when the boll weevil shall be determined to be established within their borders.

REGULATION No. 16. Shipments of cotton destined to any points in North Carolina and which originate at any point within the States of Texas, Louisiana, Mississippi, Oklahoma, Arkansas and Alabama, or other States that may hereafter become infested with cotton boll weevil, shall only be in hard compressed bales. If shipped in any other form, it is declared to be a public nuisance and is liable to seizure by the Board of Agriculture or its agents.

REGULATION No. 17. Any shipment of cotton seed which originates at any point in Texas, Louisiana, Mississippi, Oklahoma, Arkansas or Alabama, and which is destined to any point in North Carolina, can be accepted for transportation only if it shall have attached to the bill of lading a certificate or statement signed by a duly authorized State or Government Entomologist stating that the point from which said shipment originates is a locality not known to be in the area of the boll weevil infection.

REGULATION No. 18. If any shipment of seed cotton, cotton-seed hulls, cotton, or cotton seed not in accordance with these regulations be presented to any transportation company, common carrier, or agent thereof, for shipment to or delivery at any point within this State, same shall be refused, and the case shall be reported to the North Carolina State Department of Agriculture, at Raleigh, giving the name and address of the consignor and of the consignee.

Prof. Franklin Sherman, jr., Raleigh, N. C., is the quarantine officer in this State.

Oklahoma.—By virtue of rules and regulations issued by the State entomologist in accordance with the laws of the State, shipments of cotton seed, cottonseed hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, and corn in the shuck are prohibited from infested territory into uninfested territory. In the same manner household goods are prohibited unless accompanied by a certificate that no quarantined material is contained therein. Through shipments of quarantined articles shall be made in tightly closed box cars and shall not be unloaded while in transit through the State. Shipments of baled cotton into uninfested parts shall be made in tightly closed box cars. No common carrier shall use for bedding or feed for live stock any of the quarantined articles which may have originated in infested territory. All persons are expressly forbidden to send live weevils in any stage to any point in or outside of the State, either by mail, express, or otherwise.

Prof. C. E. Sanborn, Stillwater, Okla., is the quarantine agent for this State.

Porto Rico.—By legislative act no cotton seed, seed cotton, cotton lint, loose or in bales, shall be brought into the island of Porto Rico, from any State or county whatsoever without being accompanied by the certificate of a duly authorized State or Federal entomologist that the shipment originated in a locality where, by actual inspection of such official or his agent, the boll weevil was not found to exist. Shipments not so certified are liable to seizure and destruction. Punishment is provided for in section 16 of the Penal Code of Porto Rico of 1902.

The governor of the island has direct control over the enforcement of this law.

South Carolina.—In South Carolina the quarantine regulations are entirely embodied in the laws of the State, and consequently not so readily modified to conform with the changed conditions and a better understanding of the methods of dissemination of the boll weevil as

is the case when authority to promulgate rules and regulations is invested in a commission or in the State entomologist. The law established to guard against the introduction of the Mexican boll weevil into the State of South Carolina was approved on February 25, 1904. The commodities quarantined against were cotton seed, oats, and prairie hay, shipped directly or indirectly from infested points in the State of Texas.

Prof. A. F. Conradi, Clemson College, S. C., can furnish information concerning the interpretation of the State law.

Tennessee.—In compliance with the requirements of an act of the General Assembly of the State of Tennessee (S. B. No. 442, chap. 466), approved April 17, 1905, entitled "An act to create a State entomologist and plant pathologist," etc., the State board of entomology, established by said act, announced the following rules and regulations under date of December 31, 1910.

(*a*) No cotton lint (loose, baled, flat, or compressed), cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks (which have been used), or corn in the shuck, shall be shipped into Tennessee from the infested territory of Texas, Oklahoma, Louisiana, Arkansas and Mississippi.

(*b*) Shipments of household goods from infested areas of above named States shall not be admitted into Tennessee unless accompanied by an affidavit attached to the way-bill to the effect that the shipment contains no cotton lint, cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks, or corn in the shuck.

(*c*) It shall be unlawful for anyone in Tennessee to have in his possession live Mexican cotton boll weevils. The public is urged to recognize the danger of introducing unwittingly live boll weevils for inspection, observation, or experiment.

Mr. G. M. Bentley, Knoxville, Tenn., is the officer in this State.

Texas.—In accordance with an act of the State legislature, to prevent the spread and dissemination of injurious insects, the commissioner of agriculture designated the boll weevil as such an insect to be quarantined. This ruling in the act makes it illegal to ship seed cotton or cotton seed, or any other article which might carry the boll weevil from an infested county to an uninfested county.

Mr. Ed. R. Kone, Austin, Tex., is the State officer charged with quarantine enforcement.

Regulations of foreign governments.—The Governments of Egypt, Peru, and India have established an injunction against the importation of American cotton seed originating in the infested localities. In all cases, however, it can be arranged to have shipments cleared in case they are accompanied by certificates of fumigation by a competent authority.

BIBLIOGRAPHY.

This bibliography includes only the more important writings which have been published in permanent form. In the preliminary part of this bibliography a special synopsis is given of the contents of publications, more particularly to outline the history of the cultural method now recognized as of supreme importance in the control of the boll weevil. No attempt is made to give a synopsis of the later titles. For a complete annotated bibliography see Circular No. 140, Bureau of Entomology.

1843. Boheman, C. H.—Genera et species Curculionidum cum synonymia hujus familiæ ed. C. J. Schönherr, vol. 5, pt. 2, pp. 232–233.

The original description of *Anthonomus grandis*.

1871. Suffrian, E.—Verzeichniss der von Dr. Gundlach auf der Insel Cuba gesammelten Rüsselkäfer.<Archiv f. Naturg., vol. 37, Jahrg. 13, pt. 1, pp. 130–131.

Contains the record of a specimen from Cardenas and one from San Cristobal, in Cuba.

1885. Riley, C. V.—Report of the Commissioner of Agriculture for 1885, p. 279.

Contains the sentence "Another very large species, *A. grandis* Boh., we have reared at this department from dwarfed cotton bolls sent from northern Mexico by Dr. Edward Palmer." This is the first published record of the food plant and method of injury of the species.

1891. Dietz, W. G.—Revision of the genera and species of Anthonomini inhabiting North America.<Trans. Amer. Ent. Soc., vol. 18, p. 205.

The species is here reported from Texas. It has been shown, however, that this was an error. (See Insect Life, vol. 7, p. 273.)

1891. Gundlach, Juan.—Contribucion á la entomologia Cubana, vol. 3, pt. 5, p. 285.

Mentions occurrence in Cuba.

1894. Howard, L. O.—A new cotton insect in Texas.<Ins. Life, vol. 7, p. 273.

The first authentic account of the occurrence of the species in the United States, and some statements regarding its life history.

1895. Howard, L. O.—The new cotton-boll weevil.<Ins. Life, vol. 7, p. 281.

1895. Townsend, C. H. T.—Report on the Mexican cotton boll weevil in Texas (*Anthonomus grandis* Boh.).<Ins. Life, vol. 7, no. 4, pp. 295–309, figs. 30, 31, March.

An important preliminary paper giving valuable data on life history and habits, an account of its spread from Mexico to Texas, and its extent in Texas at that time. In the consideration of remedies are suggested the cutting and burning over of the cotton fields in winter, the abandonment of cotton growing over the region then infested, and the maintenance of a wide zone free from cotton along the lower Rio Grande bordering Mexico, with other suggestions of less practical value.

1895. Howard, L. O.—The Mexican cotton-boll weevil.<Cir. 6 (second series), Div. Ent., U. S. Dept. Agr., pp. 5, figs. 1–3, April.

This circular gives the results, substantially, of Mr. Townsend's field investigations of the insect in Mexico and Texas. The impracticability of the use of poisons is shown, and the collection and destruction of infested bolls and rotation of crops are suggested. English and Spanish editions were issued.

1895. Rios, J. R.—Aparicion del "picudo" en la Laguna.<El Progreso de Mex., Aug. 15, 1895. Reprinted in vol. 4, pp. 811–813, 1897.

1896. Howard, L. O.—The Mexican cotton-boll weevil.<Cir 14 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

Contains a large amount of additional information relative to distribution, natural history and habits, and natural enemies and parasites, now worked out with substantial accuracy. Under the head of remedies is the first suggestion of the great importance of the cultural method of control, and especially the early fall destruction of the cotton plants, together with the recommendation of early planting and clean cultivation. Trapping late beetles in fall and over-wintered beetles in early spring is advised, together with the destruction of volunteer plants, the region infested up to this time being fairly within the range of volunteer or seppa cotton.

1897. Howard, L. O.—The Mexican cotton-boll wevil.<Cir. 18 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

This circular brings the data on distribution and other features down to date, and in the matter of remedies incorporates the results of field studies in Texas by Mr. C. L. Marlatt on food habits and poisoning, and indicates the supreme importance of the cultural method of control, all other steps being merely palliative or to offset the failure to adopt this method. Issued in English, Spanish, and German editions.

1897. Junta de defensa contra el "picudo." (Editorial.)<El Progreso de Mex., vol. 5, pp. 8–9, Oct. 8.

1897. El picudo (*Anthonomus grandis* Boh.). (Editorial.)<Documentos referentes a su existencia en Mexico y a su invasion in los Estados Unidos del Norte. Mexico Oficina Tip. de la Secretaria de Fomento, pp. 100, figs. 1–5.

1897. Balestrier, L. de.—Las medias precautorias contra las plagas que asolan a la agricultura.<El Progreso de Mex., vol. 4, pp. 575–576, May 22.

1897. Howard, L. O.—The Mexican cotton-boll weevil in 1897. Cir. 27 (second series), Div. Ent., U. S. Dept. Agr., pp. 7.

This circular records more particularly the further spread of the weevil, and repeats the suggestions relative to the cultural method of control from Circular 18, which method is urged as a practically complete remedy for the insect.

1897. Howard, L. O.—Insects affecting the cotton plant.<Farm. Bull. 47, U. S. Dept. Agr., pp. 16–23, figs. 7–11.

Reprinted from Bulletin 33, Office of Experiment Stations, U. S. Dept. Agr., pp. 317–350.

1898. Howard, L. O.—Remedial work against the Mexican cotton-boll weevil.<Cir. 33 (second series), Div. Ent., U. S. Dept. Agr., pp. 6.

This is a supplementary circular giving the results of some experiments with poisons by Mr. Marlatt and Mr. Townsend. The cultural system of control is, however, again insisted upon.

1901. Rangel, A. F.—Estudios preliminares acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 3, pp. 93–104, pl. 9 and figure.

Deals with 45 experiments regarding destruction by means of hot air, hot water, steam, haplaphyton, and arsenic.

1901. Mally, F. W.—A preliminary report of progress of an investigation concerning the life history, habits, injuries, and methods for destroying the Mexican cotton-boll weevil (*Anthonomous* (sic) *grandis*). Authorized by special Act of the Twenty-sixth Legislature of Texas, pp. 1–30, supplement pp. 35–45.

1901. Mally, F. W.—The Mexican cotton-boll weevil.<Farm. Bull. 130, U. S. Dept. Agr., pp. 30, figs. 1–4.

A reprint, with minor corrections, of the preceding, excepting the supplement. Contains much new valuable information, but in the subject of remedies represents Mr. Mally's own point of view and not the advice of the bureau current at the same time. Nevertheless, the cultural method is again given the greatest prominence.

1901. Rangel, A. F.—Segundo informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 5, pp. 171–176.

1901. Rangel, A. F.—Tercer informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 6, pp. 197–206.

1901. Rangel, A. F.—Cuarto informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 7, pp. 245–261, pls. 16, 23.

1901. Rangel, A. F.—Quinto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 8, pp. 302–317.

1902. Ashmead, W. H.—A new Bruchophagus from Mexico.<Psyche, vol. 9, p. 324, March.

Contains the description of *Bruchophagus herreræ* n. sp., a parasite of *Anthonomus grandis*, from Coahuila, Mexico.

1902. Rangel, A. F.—Sexto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 9, pp. 403–407.

1902. Hunter, W. D.—The present status of the Mexican cotton boll weevil in the United States.<Yearbook U. S. Dept. Agr. for 1901, pp. 369–380, 1 fig.

In this publication the cultural method of control is substantially the only method recommended, augmented by the suggestion of securing northern seed and early maturing varieties to hasten the crop production; also suggests the wide spacing of rows to secure the same end.

1902. Mally, F. W.—Report on the boll weevil. Pp. 70, figs. 3. Austin, State Printer.

1902. MADERO, J. M. C.—Una plaga del algodon.<Boletin de Agricultura. (Salvador) vol. 2, no. 14, pp. 483–485, July 15.

Comments on failure of means of control as then recommended by the United States Department of Agriculture. States that cotton growing has been abandoned on account of the weevil in Coahuila, for corn and wheat.

1903. HUNTER, W. D.—Methods of controlling the boll weevil (advice based on the work of 1902).<Farm. Bul. 163, U. S. Dept. Agr., pp. 16, figs. 2, January.

The recommendations as to the steps of the cultural method are repeated in this publication, with the added suggestion of thorough cultivation and thinning of plants in the rows as well as wide spacing to hasten maturity.

1903. BARREDA, L. DE LA.—El picudo en San Pedro de la Colonia.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 2, no. 2, pp. 45–58.

1903. SANDERSON, E. D.—The Mexican boll weevil.<Cir. 1, Ent. Dept., Tex. Agr. Exp. Sta., no. 1. Press Notes, vol. 5, no. 3, pp. 8, figs. 4, February.

1903. Kill the boll weevil. How to grow cotton in the weevil district. History of the pest, its habits, and the remedies plainly disclosed. Pp. 8, figs. 4. Published by the Executive Committee of the Texas Boll Weevil Convention.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 115.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

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Issued February 5, 1915.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

U. S. DEPARTMENT OF AGRICULTURE,
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I. LIFE-HISTORY STUDIES ON THE CODLING MOTH IN MICHIGAN.

By A. G. HAMMAR, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

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By P. R. JONES AND W. M. DAVIDSON, *Entomological Assistants, Deciduous Fruit Insect Investigations.*

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ERRATA.

Page 1, after *Assistant*, replace period by comma.
Page 3, legend to figure 1, for *Emergency* read *Emergence.*
Page 32, legend to figure 1, after *Douglas* insert a comma.
Page 42, legend to Table XLII, for *emale* read *female.*
Page 161, line 20, for *Melachius* read *Malachius.*

U. S. DEPARTMENT OF AGRICULTURE,

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Issued August 9, 1912.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. QUAINTANCE, *in charge.*

FRED JOHNSON, S. W. FOSTER, P. R. JONES, F. E. BROOKS, A. G. HAMMAR, E. W. SCOTT, R. L. NOUGARET, R. A. CUSHMAN, L. L. SCOTT, J. B. GILL, A. C. BAKER, W. M. DAVIDSON, E. B. BLAKESLEE, W. B. WOOD, E. H. SIEGLER, F. L. SIMANTON, *entomological assistants.*

J. F. ZIMMER, N. S. ABBOTT, W. H. SILL, *entomological assistants, employed in enforcement of insecticide act, 1910.*

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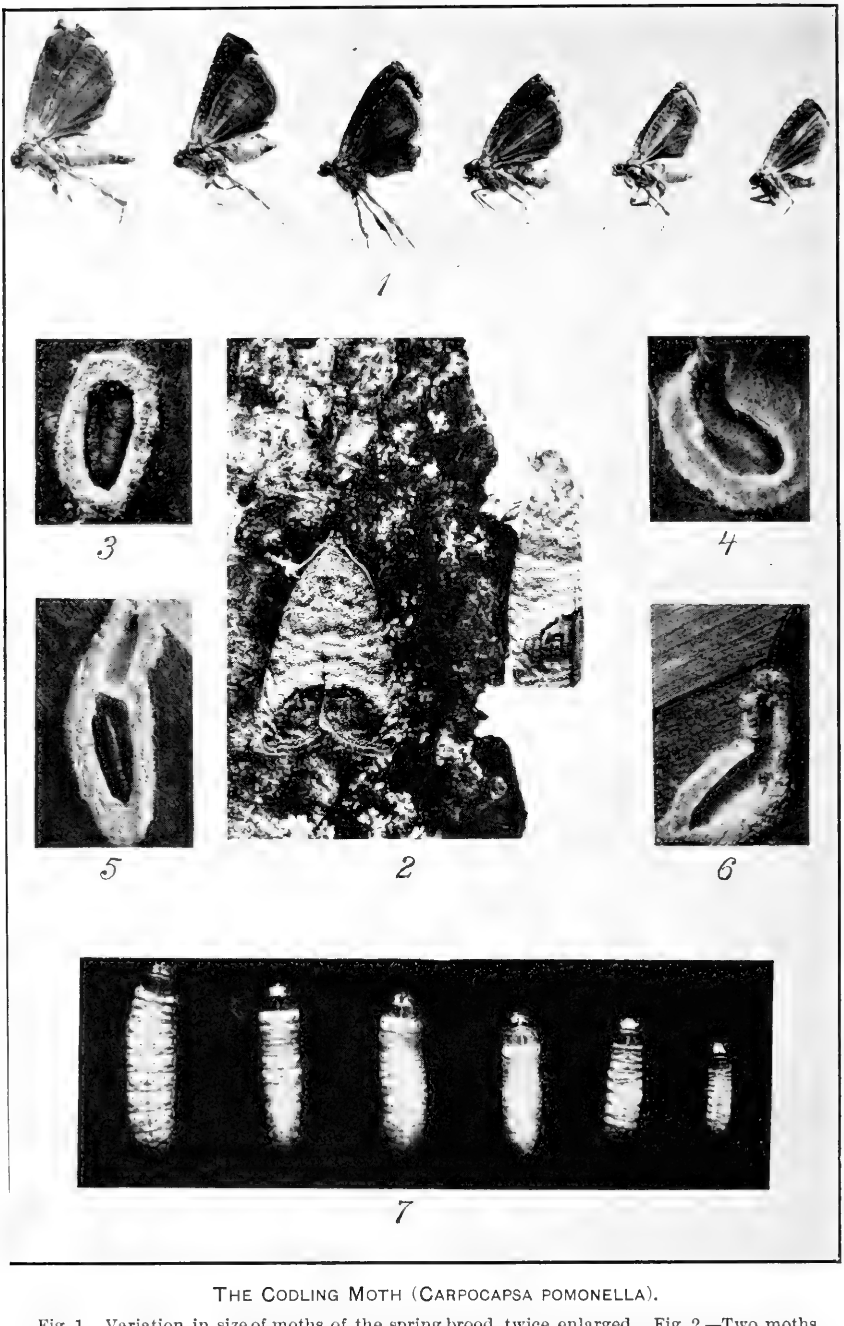


THE CODLING MOTH (CARPOCAPSA POMONELLA).

Fig. 1.—Variation in size of moths of the spring brood, twice enlarged. Fig. 2.—Two moths resting on the trunk of an apple tree, showing protective coloration; enlarged four times. Fig. 3.—Larva in winter cocoon. Fig. 4.—Larva in the act of remodeling the winter cocoon. Fig. 5.—Modified winter cocoon, with exit tube and silk partition. Fig. 6.—Cocoon after emergence of moth, enlarged. Fig. 7.—Variation in size of wintering larvæ, two and one-half times enlarged. Figs. 3-6 slightly enlarged. (Original.)

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIFE-HISTORY STUDIES ON THE CODLING MOTH IN MICHIGAN.

By A. G. Hammar,

Entomological Assistant. Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the last four years the Bureau of Entomology has maintained a temporary field station at Douglas, Mich., for the purpose of investigating certain deciduous fruit insects. As a part of this work the present paper brings together the results for 1909, 1910, and 1911 of a detailed study of the life history of the codling moth (*Carpocapsa pomonella* L.). This investigation has been conducted on the general plan of the earlier work on this insect by the bureau as reported in 1909 by E. L. Jenne in the Ozarks and in 1910 by the writer in Pennsylvania.

During the season of 1909 the rearing work was carried out by Messrs. R. W. Braucher and W. Postiff; in 1910 and 1911 by the writer, assisted by Mr. E. R. van Leeuwen. In 1911 Mr. E. H. Siegler was also detailed to assist in the rearing work and has in addition aided the writer in the preparation of the manuscript tables. Mr. E. W. Scott, conducting various spraying experiments at the field station, has contributed valuable field observations. The writer wishes to express special thanks to many of the fruit growers of the Michigan fruit belt, who have facilitated this work both with valuable information and numerous courtesies, and to Prof. A. L. Quaintance, in charge of deciduous fruit insect investigations, whose practical suggestions throughout the course of this work have been of great aid.

A duplication of many rearing experiments for 1910 and 1911 became necessary because of the unprecedented seasonal condition during the spring of 1910, when the fruit crop was to a very great extent destroyed by the sudden alternations from warm to cold weather. The season of 1911 was very exceptional for its extreme heat, which is strikingly reflected in the rate of development of the insect during that year. The rearing work during the more normal season of 1909 was greatly limited owing to the stress of other work, and the rearing experiments for that season cover merely the more essential features of the life history of the codling moth. The results thus gathered

under marked seasonal climatic variations become of particular value for comparative study, and through the duplication of certain rearing experiments better averages have been established for the time of occurrence and the duration of the separate stages of the insect.

DEFINITION OF TERMS USED.

By the use of terms which are not well defined or uniformly interpreted confusion is often likely to arise. This is particularly true in regard to the terms "brood" and "generation" applied to the codling moth. In conformity with previous papers on the codling moth the term "brood" is here used in speaking of individuals of one generation of any stage, as egg, larva, or pupa. A "generation" is considered to begin with the egg stage and to terminate with the moth or imago stage of the same generation, thus including all the stages of a life cycle. Since the wintering larvæ of the codling moth in this section of the country are of both the first and the second broods, which can be separated only by rearing, they are all referred to as "wintering larvæ" or "wintering brood of larvæ."

Similarly, the pupæ and moths that result from the wintering larvæ and issue in the spring pertain also to the two broods. It may therefore be suitable to use the terms "spring brood of pupæ," and "spring brood of moths" or briefly "spring pupæ" and "spring moths." It should be remembered that the first brood of pupæ and the first brood of moths are actually second to appear during the season. For popular purposes to avoid confusion the latter set may be called "summer pupæ" and "summer moths" and in sections where three broods exist the second-brood pupæ and moths may be termed "fall pupæ" and "fall moths."

The following plan of designating the separate stages has been uniformly followed by the bureau in the codling moth investigations:

The wintering larvæ may include larvæ of the first, second, and third broods.

The spring brood of pupæ may include pupæ of the first, second, and third broods.

The spring brood of moths may include moths of the first, second, and third broods.

The first generation includes:

- *The first brood of eggs;*
- *The first brood of larvæ,* some of which winter;
- *The first brood of pupæ,* some of which transform the same season ("summer pupæ") and a part the following spring ("spring pupæ");
- *The first brood of moths,* some of which emerge the same season ("summer moths") and some the following spring ("spring moths").

The second generation includes:

The second brood of eggs;

The second brood of larvæ, all or only a part of which may winter;

The second brood of pupæ, of which a part may transform the same season ("fall pupæ"), and a part or all the following spring ("spring pupæ").

The third generation includes:

The third brood of eggs;

The third brood of larvæ, all of which winter as larvæ;

The third brood of pupæ, which transform the following spring ("spring pupæ");

The third brood of moths, which emerge the following spring ("spring moths").

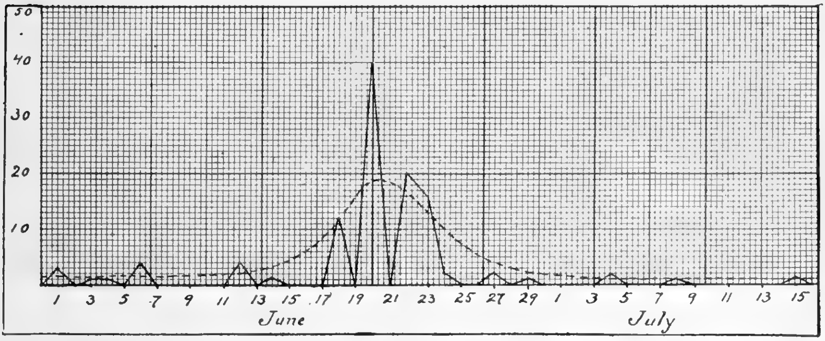


FIG. 1.—Emergency curve of spring brood of moths in 1909, at Douglas, Mich. Records of R. W. Braucher. (Original.)

SEASONAL-HISTORY STUDIES OF 1909.

The records on the life history of the codling moth during 1909 cover merely the essential features and were all made by Messrs. R. W. Braucher and W. Postiff. The experiments were conducted in an outdoor rearing shelter, and inasmuch as the rearing material was from band-record collections the results should closely represent normal conditions.

TIME OF EMERGENCE OF MOTHS OF THE SPRING BROOD.

In Table I and figure 1 is given the rate of emergence of 114 individual moths. The period for the maximum emergence is here well defined, occurring from June 17 to 24. Considering the limited number of insects used for this experiment it is very probable that isolated moths may have appeared even previous to June 1 and later than June 15, since the two broods of moths generally overlap.

TABLE I.—*Emergence of moths of the spring brood, Douglas, Mich., 1909.*

[Records by R. W. Braucher.]

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
June 1	3	June 13	1	June 23	16	July 8	1
June 3	1	June 16	3	June 24	2	Jul 15	1
June 4	1	June 18	12	June 27	2		
June 6	4	June 20	40	June 29	1		
June 12	4	June 22	20	July 4	2		

Total, 114 moths.

TIME OF EMERGENCE OF MOTHS OF THE FIRST BROOD.

The earliest moth of the first brood emerged July 28 (Table II). It will be noted from the curve of figure 2 that the maximum of emergence occurred unusually early—August 3. Throughout the month of August there was a constant and large emergence. The great irregularity of the curve in figure 2 is largely due to the fact that the banded trees from which the rearing material was obtained were only examined once a week. However, certain of the irregularities of the curve are due to climatic influences.

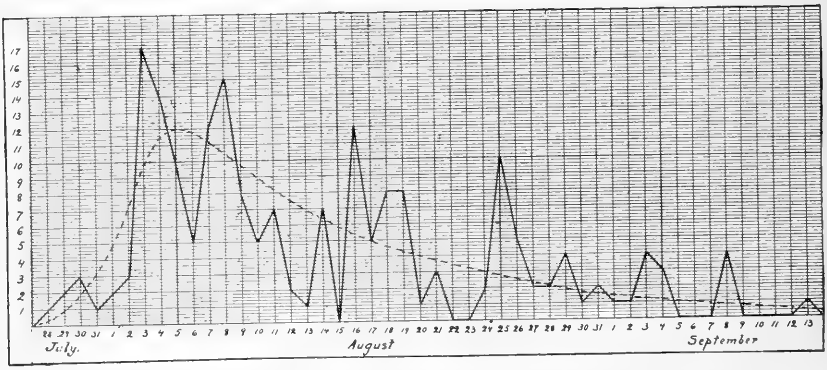


FIG. 2.—Emergence curve of first-brood moths in 1909, at Douglas, Mich. (Original.)

TABLE II.—*Emergence of moths of the first brood or summer brood at Douglas, Mich., 1909.*

[Records by W. Postiff.]

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
July 28	1	Aug. 8	15	Aug. 19	8	Aug. 30	1
July 29	2	Aug. 9	8	Aug. 20	1	Aug. 31	2
July 30	3	Aug. 10	5	Aug. 21	3	Sept. 1	1
July 31	1	Aug. 11	7	Aug. 22	....	Sept. 2	1
Aug. 1	2	Aug. 12	2	Aug. 23	....	Sept. 3	4
Aug. 2	3	Aug. 13	1	Aug. 24	2	Sept. 4	3
Aug. 3	17	Aug. 14	7	Aug. 25	10	Sept. 5	....
Aug. 4	14	Aug. 15	....	Aug. 26	5	Sept. 6	....
Aug. 5	10	Aug. 16	12	Aug. 27	2	Sept. 7	....
Aug. 6	5	Aug. 17	5	Aug. 28	2	Sept. 8	4
Aug. 7	12	Aug. 18	8	Aug. 29	4	Sept. 13	1

Total, 194 moths.

BAND-RECORD EXPERIMENTS IN 1909.

In the band-record experiments of 1909, 30 apple trees were used, of which 15 trees were located in the yard of the laboratory and 16 trees in two near-by orchards. Fall and winter apples, such as Rhode Island Greening, Baldwin, Golden Russet, Northern Spy, Wealthy, etc., were used. With these late varieties of apple a thorough test was made of the relative abundance of first and second brood larvæ. The results of these experiments are recorded in Tables III and IV and by curves in figure 3.

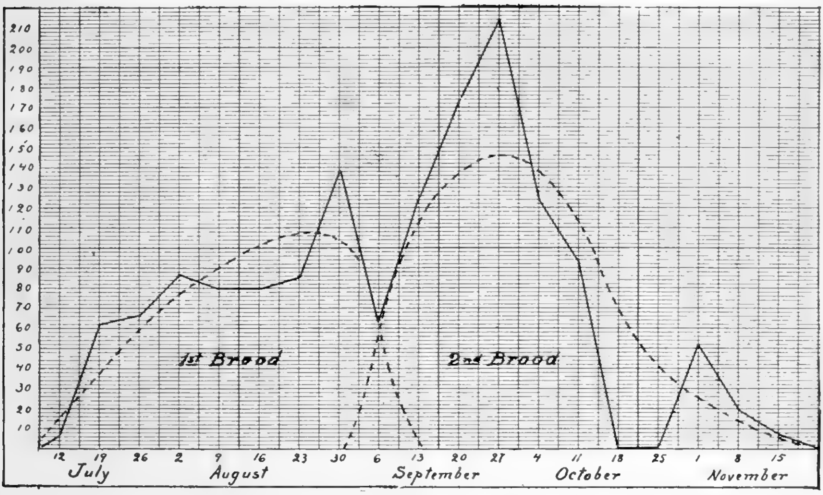


FIG. 3.—Curves showing maturity of larvæ of first and second broods; band-record curve, of 1909, at Douglas, Mich. (Original.)

TABLE III.—*Band-record experiments in 1909 at Douglas, Mich., by W. Postiff; completed in 1910 by A. G. Hammar.*

No. of record.	Date of collecting.	Number of larvæ and pupæ.	Number of moths emerged, 1909.	Number of parasites, 1909.	Number of moths emerged, 1910.	Number of parasites, 1910.	Injured and winter-killed.
1	July 12	6	6	....	....	....	....
2	July 19	62	49	4	....	....	9
3	July 26	66	49	6	....	....	11
4	Aug. 2	87	41	5	7	2	32
5	Aug. 9	81	30	2	13	1	35
6	Aug. 16	80	17	....	36	4	23
7	Aug. 23	85	1	....	61	8	15
8	Aug. 30	138	1	....	110	4	23
9	Sept. 6	62	....	....	47	1	14
10	Sept. 13	124	....	....	88	1	35
11	Sept. 20	174	....	....	119	15	40
12	Sept. 27	213	....	....	137	26	50
13	Oct. 4	124	....	....	92	12	20
14	Oct. 11	94	....	....	55	3	36
15	Oct. 18	....	....	....	....	....	....
16	Oct. 25	....	....	....	....	....	....
17	Nov. 1	51	....	....	36	2	13
18	Nov. 8	20	....	....	15	1	4
19	Nov. 15	8	....	....	5	....	3
	Total....	1,475	194	17	821	80	363

TABLE IV.—*Summary of Table III; band-record experiments at Douglas, Mich., 1909.*

Observations.	Total.	Per cent.	Observations.	Total.	Per cent.
Larvæ and pupæ collected from bands	1,475	100.0	Injured and winter-killed larvæ	363	24.6
Moths emerging:			Larvæ of the first brood	636	43.1
1909	194	13.2	Transforming larvæ of the first brood	194	33.2
1910	821	55.7	Wintering larvæ of the first brood	425	66.8
1909–1910	1,015	68.8	Larvæ of the second brood	839	56.9
Parasitized larvæ	97	6.6			

In numbers the second brood of larvæ surpassed the first quite materially. From October 18 to 25 no larvæ were obtained, due to prevailing cold weather. However, during the exceptionally warm November quite a number were collected which under average seasons would have remained undeveloped. Of the first-brood larvæ 43 per cent transformed the same season, while 57 per cent wintered together with those of the second brood. Of the total number of larvæ, 6.58 per cent proved to be parasitized by a hymenopterous fly (*Ascogaster carpocapsæ* Vier.). The proportion winter-killed and injured by other causes was 24.6 per cent.

SEASONAL-HISTORY STUDIES OF 1910.

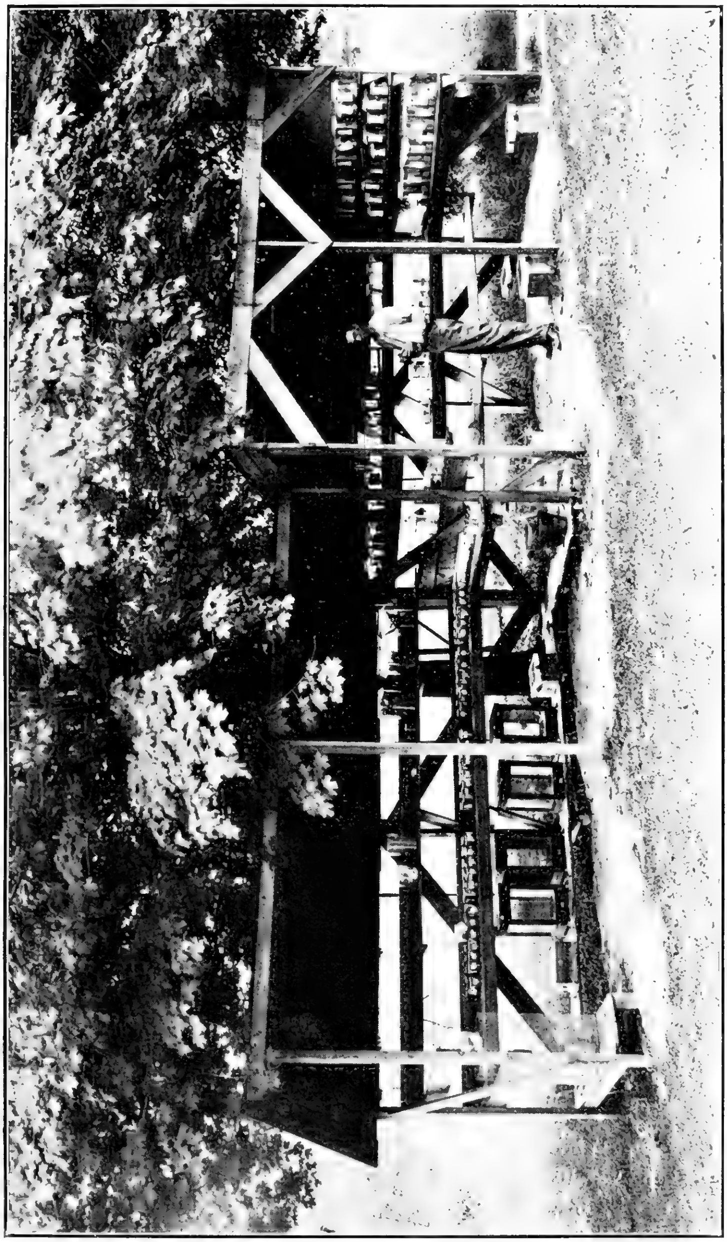
The rearing material in the spring of 1910 consisted of an abundance of wintering larvae, which had been collected from banded trees during the previous season. During the winter and throughout the progress of the rearing experiments the insects were kept in cages in an outdoor shelter (see Plate II), and were thus exposed to the normal temperature conditions.

WINTERING LARVÆ.

The wintering larvæ invariably consist of individuals of the two broods, as only a portion of the first brood transforms the same season to form the second generation of moths, while the other portion winters like all of the second-brood larvæ.

In the orchards a great number of the wintering larvæ find protection for their cocoons under the rough bark of the trees and in cracks and crevices in older trees, and many are frequently found imbedded in decayed wood. It is mainly in the latter places that the codling moth larvæ find an escape from woodpeckers and other birds which make persistent searches for the larvæ during the winter.

The cocoon of the wintering larva.—The winter cocoon of the larva is proportionately small and completely sealed, and consists of heavy walls for winter protection. In appearance these cocoons vary considerably, depending largely upon the place selected by the larvæ. Under loose bark, where the larvæ are not limited in space, the cocoons are more or less oval, as shown in Plate I, figure 3. A slight



OUTDOOR SHELTER USED IN REARING THE CODLING MOTH IN 1910 AND 1911 AT DOUGLAS, MICH. (ORIGINAL.)

depression is made in the bark, the walls along the exposed sides are constructed from fragments of bark held in place by silken threads, and the inside is finally lined with a thin layer of silk. Within the small space of the cocoon the larva will be found in a doubled-up position. In the spring, previous to pupation, the winter cocoon is partly remodeled by the larva (see Pl. I, fig. 4), and provision is made for the issuing moth by the construction of an exit tube (see Pl. I, fig. 5). This is partly made from fragments of the original wall of the cocoon and partly by the addition of new fragments of bark. Depending upon the location of the cocoon, the exit tube varies in length from one-fourth of an inch to over 1 inch. The purpose of the tube must be to provide a safe exit at the critical period of the emergence of the moth. Within the cocoon over the opening to the exit is placed a thin sheath of silk which is ruptured by the pupa at the time it wriggles out (see Pl. I, fig. 6) to give issuance to the moth.

The transforming larvæ of the first brood also make their cocoons with an exit tube. The cocoons of these larvæ, however, are only used for a short time and are hence of a more primitive construction.

Variation in size of wintering larvæ.—In size the wintering larvæ vary considerably (see Pl. I, fig. 7). There exists naturally a certain amount of individual variation, but in addition there are climatic factors which tend to increase this variation. The wintering larvæ of the first brood are for the most part fully developed. There seems to be a tendency for undersized larvæ to transform the same season, as if less fit to pass the winter. Of the second-brood larvæ there are always a number that fail to attain full growth in the fall, and others totally fail to enter hibernation before frost sets in. Larvæ parasitized by *Ascogaster carpocapsæ* are seldom more than half grown and lack the pink color of the healthy larva.

Judging from the uniformity of head measurements, the wintering larvæ, though variable in size, are probably to a great extent of the last or sixth instar. (See p. 78.)

Winter-killed larvæ.—In earlier studies of the codling moth the writer has noted that killing due to cold occurred more or less frequently among wintering larvæ. During the spring of 1910 and 1911 more definite data were obtained showing a rather high percentage of winter killing. Thus, of the total number of larvæ from the band records of 1909 (Tables III and IV), 27.6 per cent failed to develop. A mortality of about 4 per cent may be ascribed to injury from the handling of the insects, while the rest, 20 per cent, succumbed mainly to injury from cold. Under normal conditions in orchards the percentage of larvæ killed from cold is undoubtedly lower than the above figures because a proportionately large number is always destroyed during the winter by woodpeckers and nuthatches and in the spring, summer, and fall by predaceous insects and parasites.

It is quite noticeable that larvæ in exposed places or in poorly constructed cocoons are more frequently killed by cold than are those well protected.

As generally recommended under the control of the codling moth, it will be well worth while in orchards to eliminate the favorable hiding places of the larvæ, particularly the wintering brood. Such places are old stumps, decaying trunks, and branches of ill-kept trees, where cold weather little affects the larvæ or where their enemies can not readily reach them.

SPRING BROOD OF PUPÆ.

Methods of recording pupation.—On account of the fact that pupation takes place within the cocoon it is often difficult to record this transformation without disturbing the insect by exposing the cocoon.

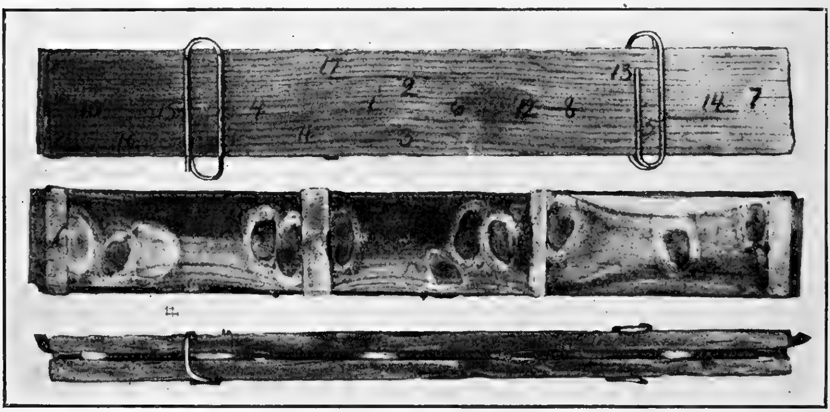


FIG. 4.—Device used in obtaining pupal records of the codling moth. (Original.)

Different workers have often used small glass vials, within which the larvæ have been compelled to make their cocoons and transform. This method is very unsatisfactory when we consider the habit of the larvæ under normal conditions. The larva, in the construction of the cocoon, either in cracks of wood or under the bark of trees, gnaws off a certain quantity of particles of wood or bark and from these the cocoon is largely made. Furthermore, under normal protection the larva suffers less from outside fluctuating temperatures than might be expected in a tube of glass.

Formerly the writer used soft strips of wood with narrow interspaces of one-eighth of an inch which the larvæ could enter and there spin their cocoons. To observe the larvæ and pupæ within it was necessary to pull the strips apart, thus exposing the cocoon. Later it was found that when a thin film of transparent celluloid was placed in the interspace so as to cover the wood on one side the larvæ produced their cocoons in a normal manner and at the same time left the

side against the celluloid more or less uncovered, so that the insects could be observed within their cocoons without disturbing the latter. Some larvæ, however, particularly when exposed to too much light, would line with silk the side of the cocoon against the film. The difficulty in such cases was overcome by cutting in the film over the cocoon a small lobe or flap which could be gently lifted for the necessary exposure. This device is illustrated in figure 4. The upper figure shows the lower side with numbers corresponding to the position of the cocoons within. In the central figure several larvæ and cocoons are seen protected by the celluloid film. The two strips of wood are held together by a pair of common paper clips which have been bent and adjusted to the shape desired.

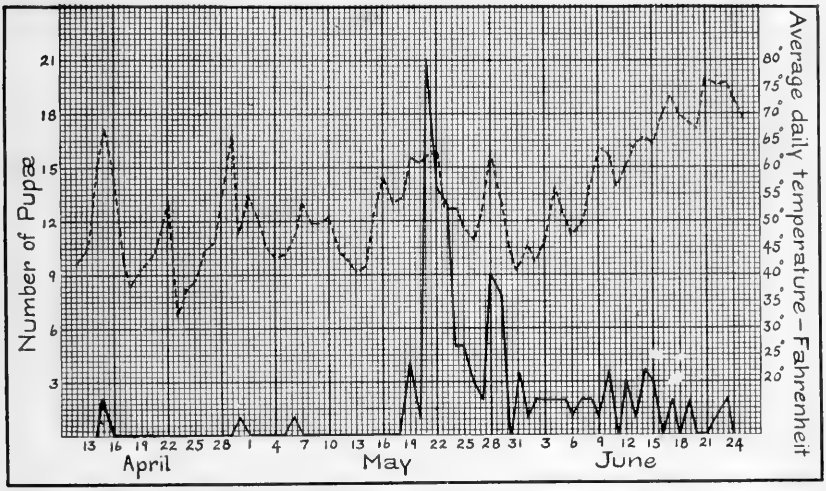


FIG. 5.—Diagram showing time of spring pupation of the codling moth in 1910, at Douglas, Mich. (Original.)

Time of pupation.—Owing to the very warm weather during the spring, pupation had commenced by April 15 (see fig. 5). However, with a change to cold weather that followed, pupation was interrupted until the latter part of May, and most of the larvæ pupated during the brief period from May 19 to May 31. The last pupa of this brood appeared on June 23. (See Table V.)

TABLE V.—*Pupation period for the codling moth in the spring of 1910, at Douglas, Mich.*

No. of larvæ.	Date of pupation.	No. of larvæ.	Date of pupation.	No. of larvæ.	Date of pupation.	No. of larvæ.	Date of pupation.
2	Apr. 15	5	May 25	2	June 4	4	June 14
1	Apr. 30	3	May 26	2	June 5	3	June 15
1	May 6	2	May 27	1	June 6	2	June 17
4	May 19	9	May 28	2	June 7	2	June 19
1	May 20	8	May 29	2	June 8	1	June 22
21	May 21	4	May 31	1	June 9	2	June 23
14	May 22	1	June 1	4	June 10		
13	May 23	2	June 2	3	June 12		
5	May 24	2	June 3	1	June 13		

Length of spring pupal stage.—The results of observations on the time of pupation and emergence of 106 individual insects are given in Table VI. Those pupating in April remained in this stage for the exceptionally long period of 59 days. The majority, pupating during the latter half of May, remained in the pupal stage about 30 days, while later larvæ, pupating about June 15, remained in this stage only 10 to 15 days. (See Table VI.) The average for the entire spring brood of pupæ was 26.02 days.

TABLE VI.—*Length of pupal stage of the spring brood, Douglas, Mich., 1910.*

No. of observation.	Date of—		Days.	No. of observation.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	Apr. 15	June 13	59	54	May 25	June 22	28
2	Apr. 30	June 15	46	55	...do.......	...do.......	28
3	May 6	June 17	42	56	...do.......	...do.......	28
4	May 19	June 18	30	57	...do.......	...do.......	28
5	...do.......	June 19	31	58	...do.......	June 23	29
6	...do.......	...do.......	31	59	May 26	June 22	27
7	...do.......	June 20	32	60	...do.......	...do.......	27
8	May 20	...do.......	31	61	...do.......	June 23	28
9	May 21	June 18	28	62	May 27	June 22	26
10	...do.......	June 19	29	63	...do.......	...do.......	26
11	...do.......	June 20	30	64	May 28	...do.......	25
12	...do.......	...do.......	30	65	...do.......	...do.......	25
13	...do.......	...do.......	30	66	...do.......	...do.......	25
14	...do.......	...do.......	30	67	...do.......	June 23	26
15	...do.......	...do.......	30	68	...do.......	...do.......	26
16	...do.......	...do.......	30	69	...do.......	...do.......	26
17	...do.......	...do.......	30	70	...do.......	...do.......	26
18	...do.......	June 21	31	71	...do.......	...do.......	26
19	...do.......	...do.......	31	72	May 29	June 19	21
20	...do.......	...do.......	31	73	...do.......	June 23	25
21	...do.......	...do.......	31	74	...do.......	...do.......	25
22	...do.......	...do.......	31	75	...do.......	...do.......	25
23	...do.......	...do.......	31	76	...do.......	...do.......	25
24	...do.......	...do.......	31	77	May 31	...do.......	23
25	...do.......	...do.......	31	78	...do.......	...do.......	23
26	...do.......	June 22	32	79	June 1	...do.......	22
27	...do.......	June 24	34	80	June 2	...do.......	21
28	May 22	June 21	30	81	...do.......	June 24	22
29	...do.......	...do.......	30	82	June 3	June 23	20
30	...do.......	...do.......	30	83	...do.......	June 24	21
31	...do.......	...do.......	30	84	June 4	June 23	19
32	...do.......	...do.......	30	85	June 5	...do.......	18
33	...do.......	...do.......	30	86	...do.......	...do.......	18
34	...do.......	...do.......	30	87	June 6	...do.......	17
35	...do.......	...do.......	30	88	June 7	June 24	17
36	...do.......	...do.......	30	89	...do.......	...do.......	17
37	...do.......	...do.......	30	90	June 8	...do.......	16
38	...do.......	June 22	31	91	June 9	June 25	16
39	...do.......	June 23	32	92	June 10	June 20	10
40	...do.......	...do.......	32	93	...do.......	June 24	14
41	May 23	June 21	29	94	...do.......	June 25	15
42	...do.......	...do.......	29	95	...do.......	June 26	16
43	...do.......	...do.......	29	96	June 12	...do.......	14
44	...do.......	June 22	30	97	...do.......	June 27	15
45	...do.......	...do.......	30	98	...do.......	...do.......	15
46	...do.......	...do.......	30	99	June 13	...do.......	14
47	...do.......	...do.......	30	100	June 14	June 28	14
48	...do.......	...do.......	30	101	...do.......	June 29	15
49	...do.......	...do.......	30	102	June 15	June 28	13
50	...do.......	...do.......	30	103	...do.......	June 29	14
51	May 24	...do.......	29	104	June 17	July 2	15
52	...do.......	...do.......	29	105	June 19	June 29	10
53	...do.......	June 28	35	106	June 23	July 8	15
Average							26.02
Maximum							59
Minimum							10

TABLE VII.—*Length of pupal stage of the spring brood, Douglas, Mich., 1910; summary of Table VI.*

Number of observations.	Pupal period.	Number of observations.	Pupal period.	Number of observations.	Pupal period.	Number of observations.	Pupal period.
	Days.		*Days.*		*Days.*		*Days.*
2	10	1	19	2	27	1	35
1	13	1	20	6	28	1	42
5	14	3	21	7	29	1	46
6	15	2	22	25	30	1	59
3	16	2	23	12	31		
3	17	7	25	4	32		
2	18	7	26	1	34		

SPRING BROOD OF MOTHS.

Time of emergence (fig. 6, p. 12).—Notwithstanding the changeable weather conditions during the spring of 1910 the codling moths emerged with striking uniformity. The earliest moth in the rearing cages appeared June 13; the great majority of moths emerged between June 18 and June 30; isolated moths continued to appear up to the close of July, when the first moths of the summer brood commenced to issue. The maximum emergence took place June 22. The emergence for the spring brood is given in Table VIII.

TABLE VIII.—*Time of emergence of the spring brood of moths during 1910, at Douglas, Mich.*

Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.
5	June 13	59	June 25	7	July 7	....	July 19
5	June 14	56	June 26	6	July 8	....	July 20
1	June 15	81	June 27	6	July 9	2	July 21
4	June 16	36	June 28	[illegible]	July 10	....	July 22
17	June 17	45	June 29	5	July 11	1	July 23
40	June 18	53	June 30	8	July 12	....	July 24
52	June 19	33	July 1	....	July 13	....	July 25
82	June 20	34	July 2	6	July 14	....	July 26
162	June 21	19	July 3	....	July 15	2	July 27
232	June 22	9	July 4	....	July 16		
199	June 23	10	July 5	6	July 17		
128	June 24	10	July 6	....	July 18		

Variation in size of moths of the spring brood.—The moths of the spring brood vary considerably in size and to a greater extent than do those of the summer brood. (See Pl. I, fig. 1.) This might be expected on considering the difference in size of the wintering larvæ from which the moths result.

There have often appeared dwarfed specimens of moths from the band-record material which at first sight could hardly be recognized to be of the codling-moth species. That there should exist a corresponding difference in the vitality of individual moths is only natural and is fully reflected in many of the results of the rearing experiments. In view of the great variability in behavior of the insect it has been necessary to conduct many of the experiments on a large scale in order to establish reliable averages.

Time of oviposition.—The time of oviposition in orchards may be determined with fair precision from the combined data on the habits of the moths in captivity, the rearing experiments, and the field observations. In rearing these insects eggs may be readily obtained by confining a number of moths together in cages. It is not possible to determine the number of eggs thus produced, but the time and period of egg deposition can be ascertained.

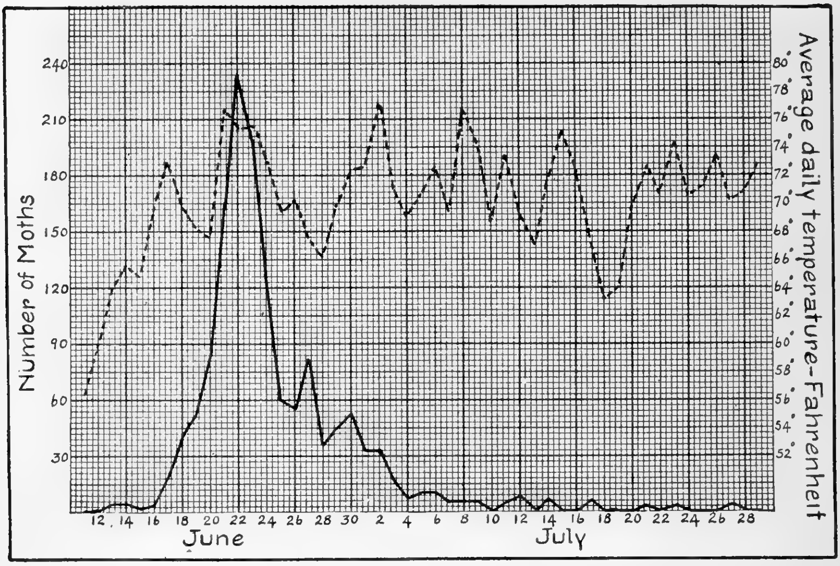


FIG. 6.—Emergence curve of spring brood of moths in 1910, at Douglas, Mich. (Original.)

TABLE IX.—*Egg deposition of the spring brood of moths in cages in 1910, at Douglas, Mich.*

No. of cage.	Number of moths.	Date of— Emergence.	Date of— First oviposition.	Date of— Last oviposition.	Number of days— Before first oviposition.	Number of days— Of egg deposition.	Number of days— From date of emergence to last oviposition.
1	5	June 14	June 19	June 21	5	3	7
2	3	June 16	June 20	.....do.....	4	2	5
3	15	June 17	June 19	June 25	2	7	8
4	36	June 18	June 20	June 26	2	7	8
5	57	June 19	.....do.....	June 27	1	.8	8
6	87	June 20	June 23	June 29	3	7	9
7	262	June 22	.....do.....	July 4	1	12	12
8	25	June 24	June 29	July 2	5	4	8
9	29	June 25	.....do.....	July 10	4	12	15
10	27	June 27	July 2	July 7	5	6	10
11	16	June 28	July 1	July 3	3	3	5
12	24	June 29	July 2	July 10	3	9	11
13	36	June 30	July 3	July 9	3	7	9
14	25	July 2	July 9	.....do.....	7	1	7
15	8	July 6	July 8	July 11	2	4	5
16	5	July 9	July 11	.....do.....	2	1	2
17	5	July 11	July 14	July 14	3	1	3
Average number of days					3.24	5.53	7.76
Maximum number of days					7	12	15
Minimum number of days					1	1	2

In Table IX are given the results from 17 separate "stock-jar" experiments, so called because of the nature of these experiments. Medium-sized glass jars of about 1 gallon capacity were found to be well suited for the purpose. To provide for a certain amount of moisture a layer of damp sand was put in each jar; food was furnished the moths in the form of diluted sugar and honey solution placed on a small piece of sponge. In each cage a certain number of moths, of known date of emergence, was confined, and throughout the course of the experiments a daily record was kept of egg deposition and the length of life of the moths. The eggs were laid indiscriminately all over the cage, on the sand, on the sides of the glass, on apple foliage and fruit, and on the cloth cover of the jars. When too many moths were confined together eggs were even placed on the wings and backs of some of the moths. For the purpose of recording the egg stage it was found desirable to have the moths oviposit on pear leaves in place of fruit because the leaves darken upon withering, so that the light-colored semitransparent eggs may be better observed. Each day fresh foliage was placed in the cages, which insured eggs of a given date of deposition.

On an average the moths commenced to oviposit three days after the date of emergence and most of the eggs were laid within a week of emergence. In a few extreme cases eggs were laid the second day after emergence. In one instance the last eggs were laid 15 days after the date of emergence. (See Table IX.) Several moths in the stock jars survived from 19 to 25 days.

Length of life of moths.—A summary of observations on the life of 529 moths is given in Tables X and XI. The average length of life was 9.44 days, the maximum 25 days, and the minimum 2 days. These moths were from the stock-jar experiments previously described.

TABLE X.—*Summary of observations on the length of life of 529 moths of the spring brood in confinement, Douglas, Mich., 1910.*

Number of moths.	Number of days.	Number of moths.	Number of days.	Number of moths.	Number of days.	Number of moths.	Number of days.
8	2	118	8	60	13	9	18
1	3	16	9	14	14	6	19
8	5	47	10	7	15	1	20
74	6	28	11	9	16	1	25
70	7	44	12	8	17		

TABLE XI.—*Summary of Table X. Length of life of moths of the spring brood, 1910.*

	Days alive.
Average	9.44
Maximum	25
Minimum	2

THE FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation.—The eggs of the first brood on an average hatched within 6 or 7 days. Under low temperature the maximum length of time was 10 days. The shortest period of incubation was 4 days. (See Table XII.)

TABLE XII.—*Incubation period of eggs of the first brood laid in rearing cages, Douglas, Mich., 1910.*

No. of observation.	Date of egg deposition.	Date of—			Duration of—		
		Appearance of red ring.	Appearance of black spot.	Hatching.	Red ring.	Black spot.	Incubation.
					Days.	*Days.*	*Days.*
1	June 20			June 29			9
2	do			June 30			10
3	June 22		June 28	June 29		6	7
4	do		do	June 30		6	8
5	June 24			July 1			7
6	June 25			July 2			7
7	June 26			do			6
8	June 27			July 3			6
9	June 28			July 4			6
10	do			July 5			7
11	June 29		July 3	July 4		4	5
12	do		do	July 5		4	6
13	June 30	July 3	July 5	July 6	3	5	6
14	do	do	do	July 7	3	5	7
15	July 1	do	July 6	do	2	5	6
16	do	do	do	July 8	2	5	7
17	July 2	July 5	July 7	do	3	5	6
18	July 3	July 6	July 8	July 9	3	5	6
19	do	do	do	July 10	3	5	7
20	July 4	do	July 9	do	2	5	6
21	do	do	July 10	July 12	2	6	8
22	July 6	July 9	July 11	July 13	3	5	7
23	do	do	do	July 14	3	5	8
24	July 7	do	do	July 13	2	4	6
25	July 8	July 10	July 12	July 14	2	4	6
26	July 9	July 12	July 14	July 15	3	5	6
27	do	July 13	do	July 16	4	5	7
28	July 12	July 14	July 15	do	2	3	4
29	do	do	do	July 17	2	3	5
30	do	do	July 16	July 18	2	4	6
Average					2.5	4.7	6.6
Maximum					4	6	10
Minimum					2	3	4

The so-called "red ring" of the egg appeared from two to three days after egg deposition, and the "black spot" from one to two days previous to hatching.

The eggs used in these experiments were laid in cages on pear foliage. Records on the development of the eggs were taken once daily between 9 and 10 o'clock in the morning.

FIRST BROOD OF LARVÆ.

Time of hatching.—In the field the actual time of hatching and the relative abundance of newly hatched larvæ may be fairly well determined from the different data on hand relative to the time of emergence of the moths, egg deposition, incubation of eggs, length of feeding of larvæ, and the appearance of mature larvæ, as shown by the band records. In correlating these facts the time of hatching is established as given in the diagram of figure 11.

The earliest eggs were deposited June 17, the maximum oviposition was reached at the close of June, and a few late eggs were laid up to

the end of July. Incubation of the earliest eggs lasted nine days; for eggs laid about June 30, six days; and for later ones laid during the middle and latter part of July, only four to five days. The larvæ from the Saugatuck band records (fig. 9) reach a maximum July 31, and inasmuch as the average length of feeding for this brood of larvæ was 27 days the date for the maximum hatching would be July 4. On the other hand, on the basis of oviposition and length of incubation the height of the hatching period would be July 6.

Length of feeding.—Reference has already been made in the previous pages to the fact that a portion of the first-brood larvæ do not transform the same year, but winter and complete the life cycle the following year. The transforming and wintering larvæ differ in the length of feeding, and the latter are often materially larger in size. Thus on an average the transforming larvæ remained in the fruit 25 days against 29 days for the wintering larvæ. (See Tables XVI and XVII.) For the entire brood of larvæ the shortest feeding period was 17 days, the longest 45 days.

Time of maturity of larvæ.—In the field the time of maturity of the larvæ is determined from the band-record experiments (fig. 9 and Table XXVIII). Thus the period for the first-brood larvæ at Douglas, Mich., extended from July 10 to September 10. After the emergence of the moths from the band-record collection it may further be possible to determine the time of maturity of transforming and wintering larvæ of this brood. The last transforming larva left the fruit August 8 and the first wintering larvæ left the fruit July 20. There is also a difference in the appearance of cocoons whereby the two sets of larvæ may be recognized; the transforming larva provides the cocoon with an exit tube, while the wintering larva produces a closed cocoon. (For full description see pp. 6–7.)

Percentages of transforming and wintering larvæ.—From Table XXXI it will be found that 201 larvæ of the first brood transformed the same season, while 368 wintered, or 35 per cent transformed and 64.1 per cent wintered.

Somewhat similar results were obtained from the rearing experiments, though these can not be as reliable as the data from the band-record experiments, since the former are from a limited number of observations. Out of a total of 51 larvæ, 21 transformed and 30 wintered, or 40 per cent transformed and 60 per cent wintered. (See Table XXII.)

Larval life in the cocoon.—The length of time required for the making of the cocoon depends largely upon whether the larva is to transform the same season or to winter. A slight individual variation of time naturally does exist for either set of larvæ. In case of wintering larvæ it is difficult to decide just when the cocoon is completed. The transforming larvæ cease to be active from two to three days before pupating. For these, then, the larval life in the cocoon can be readily determined, being considered as the period from the time of leaving the fruit to the time of pupation.

In Table XIII are given the results from observations on 117 individual insects. Further records on the same topic are found in Table XVI. The larval life in the cocoon varied from 3 to 15 days with an average of 7 days. In case of a very short period of from 3 to 5 days the larvæ abandoned its first cocoon and made a new one. The records, however, only show the time consumed for the making of the last cocoon. Such cocoons are very primitive in appearance and have not been completed.

TABLE XIII.—*Length of the pupal stage of the first brood, Douglas, Mich., 1910.*

No. of observation.	Date of—			Larvæ in cocoon.	Pupal period.	No. of observation.	Date of—			Larvæ in cocoon.	Pupal period.
	Leaving fruit.	Pupation.	Emergence.				Leaving fruit.	Pupation.	Emergence.		
				Days.	*Days.*					*Days.*	*Days.*
1	July 22	July 25	Aug. 9	3	15	60	July 29	Aug. 4	Aug. 20	6	16
2	...do....	July 26	...do....	4	14	61	July 30	...do....	Aug. 17	5	13
3	...do....	...do....	...do....	4	14	62	...do....	...do....	...do....	5	13
4	...do....	...do....	...do....	4	14	63	...do....	...do....	...do....	5	13
5	...do....	...do....	Aug. 13	4	18	64	...do....	...do....	Aug. 18	5	14
6	...do....	...do....	Aug. 15	4	20	65	...do....	...do....	...do....	5	14
7	...do....	...do....	...do....	4	20	66	...do....	...do....	...do....	5	14
8	...do....	...do....	Aug. 20	4	25	67	...do....	...do....	...do....	5	14
9	...do....	Aug. 6	Aug. 19	15	13	68	...do....	...do....	Aug. 19	5	15
10	...do....	...do....	Aug. 20	15	14	69	...do....	...do....	Aug. 21	5	17
11	July 23	July 29	Aug. 13	6	15	70	...do....	Aug. 5	Aug. 18	6	13
12	...do....	Aug. 4	Aug. 17	12	13	71	...do....	Aug. 6	...do....	7	12
13	...do....	...do....	...do....	12	13	72	...do....	...do....	Aug. 21	7	15
14	July 25	July 30	Aug. 15	5	16	73	...do....	Aug. 7	Aug. 18	8	11
15	...do....	Aug. 1	...do....	7	14	74	...do....	Aug. 9	Aug. 21	10	12
16	...do....	Aug. 3	...do....	9	12	75	...do....	...do....	...do....	10	12
17	...do....	...do....	...do....	9	12	76	...do....	...do....	...do....	10	12
18	...do....	...do....	Aug. 16	9	13	77	...do....	...do....	Aug. 24	10	15
19	...do....	...do....	...do....	9	13	78	July 31	Aug. 4	Aug. 17	4	13
20	July 26	...do....	...do....	8	13	79	...do....	...do....	...do....	4	13
21	...do....	...do....	...do....	8	13	80	...do....	...do....	Aug. 18	4	14
22	...do....	...do....	...do....	8	13	81	...do....	Aug. 5	...do....	5	13
23	...do....	...do....	...do....	8	13	82	...do....	Aug. 6	Aug. 19	6	13
24	...do....	...do....	...do....	8	13	83	...do....	...do....	Aug. 20	6	14
25	...do....	...do....	Aug. 18	8	15	84	...do....	Aug. 7	...do....	7	13
26	...do....	Aug. 4	Aug. 17	9	13	85	...do....	...do....	Aug. 21	7	14
27	July 27	Aug. 3	Aug. 13	7	10	86	...do....	Aug. 9	Aug. 22	9	13
28	...do....	...do....	Aug. 15	7	12	87	...do....	...do....	...do....	9	13
29	...do....	...do....	...do....	7	12	88	Aug. 1	Aug. 4	Aug. 18	3	14
30	...do....	...do....	...do....	7	12	89	...do....	Aug. 5	Aug. 19	4	14
31	...do....	...do....	...do....	7	12	90	...do....	Aug. 6	Aug. 18	5	12
32	...do....	...do....	Aug. 16	7	13	91	...do....	...do....	Aug. 19	5	13
33	...do....	...do....	...do....	7	13	92	...do....	...do....	Aug. 20	5	14
34	...do....	...do....	...do....	7	13	93	...do....	...do....	...do....	5	14
35	...do....	...do....	Aug. 18	7	15	94	...do....	...do....	...do....	5	14
36	...do....	...do....	...do....	7	15	95	...do....	Aug. 8	Aug. 21	7	13
37	...do....	Aug. 4	Aug. 15	8	11	96	...do....	Aug. 9	...do....	8	12
38	...do....	...do....	Aug. 18	8	14	97	...do....	...do....	Aug. 22	8	13
39	...do....	Aug. 6	Aug. 20	10	14	98	Aug. 4	Aug. 12	...do....	8	10
40	July 28	Aug. 3	Aug. 15	6	12	99	...do....	Aug. 13	Aug. 25	9	12
41	...do....	...do....	Aug. 16	6	13	100	...do....	Aug. 14	Aug. 26	10	12
42	...do....	...do....	...do....	6	13	101	...do....	Aug. 15	Aug. 29	11	14
43	...do....	...do....	Aug. 17	6	14	102	...do....	...do....	Aug. 30	11	15
44	...do....	Aug. 4	...do....	7	13	103	Aug. 5	Aug. 13	Aug. 24	8	11
45	...do....	...do....	...do....	7	13	104	...do....	Aug. 14	Aug. 25	9	11
46	...do....	...do....	...do....	7	13	105	...do....	Aug. 17	Aug. 30	12	13
47	...do....	...do....	Aug. 18	7	14	106	Aug. 7	Aug. 15	Aug. 27	8	12
48	...do....	...do....	...do....	7	14	107	Aug. 8	Aug. 14	Aug. 25	6	11
49	...do....	...do....	...do....	7	14	108	...do....	Aug. 15	Aug. 24	7	9
50	...do....	...do....	...do....	7	14	109	...do....	Aug. 16	Aug. 30	8	14
51	...do....	Aug. 5	Aug. 19	8	14	110	...do....	Aug. 17	Sept. 1	9	15
52	...do....	...do....	...do....	8	14	111	...do....	...do....	...do....	9	15
53	...do....	Aug. 9	Aug. 22	12	13	112	Aug. 9	Aug. 15	Aug. 26	6	11
54	July 29	Aug. 3	Aug. 16	5	13	113	...do....	Aug. 16	Aug. 30	7	14
55	...do....	...do....	...do....	5	13	114	Aug. 10	Aug. 15	Aug. 29	5	14
56	...do....	Aug. 4	Aug. 17	6	13	115	Aug. 16	Aug. 25	Sept. 14	9	20
57	...do....	...do....	Aug. 18	6	14	116	...do....	...do....	...do....	9	20
58	...do....	...do....	...do....	6	14	117	...do....	Aug. 26	...do....	10	19
59	...do....	...do....	...do....	6	14						
Average										7.1	13.6
Maximum										15	25
Minimum										3	9

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—The time of pupation may be determined from the records of the pupal stage and the emergence of moths of the same brood (see fig. 11) since it is to be expected that the rate of pupation approximates that of the emergence of the moths resulting from these pupæ.

TABLE XIV.—*Length of the pupal stage of the first brood, Douglas, Mich., 1910; summary of Table XIII.*

Number of observations.	Larvæ in cocoon.	Number of observations.	Pupal period.
	Days.		*Days.*
2	3	1	9
11	4	2	10
19	5	6	11
15	6	16	12
25	7	38	13
17	8	33	14
13	9	11	15
7	10	2	16
2	11	1	17
4	12	1	18
2	15	1	19
		4	20
		1	25

Length of pupal stage (Tables XIII and XIV).—The pupal stage of the first brood varied from 9 to 25 days with an average of 13.6 days. The experiments of Table XIII include observations taken during the greater part of the pupal period.

TABLE XV.—*Time of emergence of moths of the summer brood from band-collected material of 1910.*

Date of emergence.	Number of moths from band records at—				Date of emergence.	Number of moths from band records at—			
	New Richmond.	Saugatuck.	Lake Shore.	Total.		New Richmond.	Saugatuck.	Lake Shore.	Total.
July 26	2	....	....	2	Aug. 16	5	14	12	31
July 27	2	....	....	2	Aug. 17	3	10	12	25
July 28	4	....	6	10	Aug. 18	4	3	13	20
July 29	4	1	6	11	Aug. 19	2	11	10	23
July 30	4	....	4	8	Aug. 20	6	9	10	25
July 31	7	2	....	9	Aug. 21	....	10	8	18
Aug. 1	9	5	14	28	Aug. 22	8	21	28	57
Aug 2	2	16	7	25	Aug. 23	3	8	5	16
Aug. 3	7	8	10	25	Aug. 24	....	6	9	15
Aug. 4	4	3	6	13	Aug. 25	....	6	4	10
Aug. 5	1	4	3	8	Aug. 26	....	5	....	5
Aug. 6	11	5	8	24	Aug. 27	2	....	6	8
Aug. 7	6	4	3	13	Aug. 28	....	5	....	5
Aug. 8	12	4	8	24	Aug. 29	....	1	5	6
Aug. 9	10	4	9	23	Aug. 30	1	2	2	5
Aug. 10	3	9	6	18	Aug. 31	1	....	1	2
Aug. 11	6	1	5	12	Sept. 1	1	....	....	1
Aug. 12	6	1	7	14	Sept. 7	....	2	3	5
Aug. 13	6	7	5	18	Sept. 8	....	....	1	1
Aug. 14	8	9	9	26					
Aug. 15	3	5	17	25	Total..	153	201	262	762

FIRST BROOD OF MOTHS, OR SUMMER MOTHS.

Time of emergence (fig. 7 and Table XV).—The records of emergence of the first brood of moths are from band-record material and should closely represent the actual time and rate of appearance of moths in the field. The larvæ used in these experiments were from three separate band records (see Table XV), and the curve of figure 7 represents the sum total of daily emergence from the combined sources. The first moth appeared July 26; a maximum of emergence occurred August 22, after which date only a few moths issued; the last moth of the brood emerged September 8.

From the point of view of mechanical control the time of emergence of moths of the second brood of the codling moth becomes of foremost

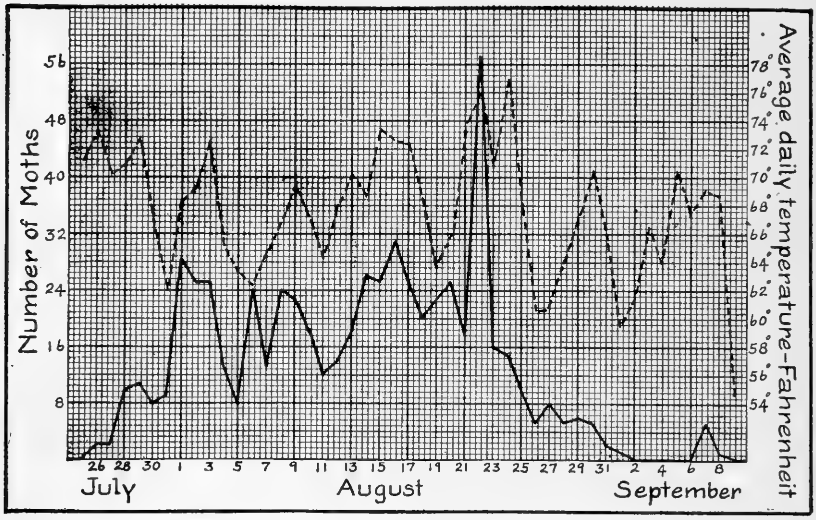


FIG. 7.—Emergence curve of summer brood of moths in 1910, at Douglas, Mich. (Original.)

importance, and this is one of the phases in the life history of the insect in which the literature on the codling moth is particularly deficient. This is mainly because of the difficult task of establishing accurate data, which at present involves carefully conducted band-record experiments. It is necessary that the bands be started in proper time and that the larvæ be collected at regular and preferably at short intervals (three days) in order that the records on the emergence of moths may become fully reliable.

Time of oviposition.—The so-called stock-jar experiments of Table XVI, including moths of the first brood, have been carried out under identically similar conditions as described on page 13 for the spring brood of moths. Egg deposition commenced from two to three days after the time of emergence of the moths, and extended on an average over a period of one week. In one instance eggs were laid 18 days after the date of emergence of the moths.

TABLE XVI.—*Egg deposition of the summer brood of moths in rearing cages, Douglas, Mich., 1910.*

No. of experiment.	Number of moths.	Date of— Emergence of moths.	First oviposition.	Last oviposition.	Number of days— Before first oviposition.	Of egg deposition.	From date of emergence to last oviposition.
1	10	Aug. 11	Aug. 14	Aug. 19	3	6	8
2	10	Aug. 12	Aug. 16	Aug. 24	4	9	12
3	26	Aug. 14	...do....	Sept. 1	2	17	18
4	20	Aug. 16	Aug. 19	Aug. 25	3	7	9
5	30	Aug. 17	...do....	...do....	2	7	8
6	20	Aug. 18	Aug. 20	Aug. 26	2	7	8
7	27	Aug. 19	Aug. 22	Aug. 25	3	4	6
8	30	Aug. 20	...do....	Aug. 29	2	8	9
9	10	Aug. 21	Aug. 25	Aug. 28	4	4	7
10	53	Aug. 22	Aug. 24	Aug. 26	2	3	4
11	11	Aug. 23	Aug. 25	Aug. 25	2	1	2
Average					2.6	6.6	8.2
Maximum					4	17	18
Minimum					2	1	2

Egg deposition by individual moths.—Observations were taken on the egg deposition of six individual moths in captivity as given in Tables XVII, XVIII, and XIX. In most of these experiments pairs of male and female moths were used, which were removed from the stock jars before any oviposition had taken place.

TABLE XVII.—*Egg deposition by individual moths of the summer brood, Douglas, Mich., 1910.*

Date of egg deposition.	Number of individual moths. 1	2	3	4	5	6
Date of emergence.	July 28.	Aug. 4.	Aug. 10.	Aug. 11.	Aug. 14.	Aug. 15.
Aug. 5	27	....	....	....	....	....
Aug. 7	6	....	....	....	....	....
Aug. 8	11	36	....	....	....	....
Aug. 9	6	13	....	....	....	....
Aug. 10	8	22	....	....	....	....
Aug. 11	10	....	....	....	....	....
Aug. 12	17	....	....	....	....	....
Aug. 13	6	....	....	....	....	....
Aug. 15	....	....	5	....	....	....
Aug. 16	....	....	4	....	....	....
Aug. 17	....	....	7	1	....	1
Aug. 18	....	....	2	1	....	1
Aug. 19	....	....	....	3	3	....
Aug. 20	....	....	....	2	6	....
Aug. 21	....	....	....	4	8	2
Aug. 22	....	....	....	....	....	3
Date of death of moths.	Aug. 14	Aug. 12.	Aug. 25.	Aug. 23.	Aug. 24.	Aug. 26.

The moths of experiment No. 2 were found mating at 10.30 a. m., August 6, or two days previous to the first egg deposition. On an average the first eggs were laid five days after the emergence of the moths and for an average period of five days; the maximum number of eggs per female was 91; the average number of eggs per female, 35.8. These figures are lower than those from similar but later experiments in 1911.

TABLE XVIII.—*Egg deposition by individual moths of the summer brood; summary of Table XVII.*

Observations.	Number of individual months.					
	1	2	3	4	5	6
Total eggs per female	91	71	18	11	17	7
Days before egg deposition	8	4	5	6	5	2
Days duration of egg deposition	9	3	4	5	3	6
Days alive after egg deposition	1	2	7	2	3	4
Days moths lived	17	8	15	12	10	11

TABLE XIX.—*Egg deposition by individual moths of the summer brood; summary of Table XVII.*

Observations.	Average.	Maximum.	Minimum.
Eggs per female	35.8	91	7
Eggs per day per female	7.16	36	1
Days before egg deposition per female	5	8	2
Days of egg deposition per female	5	9	3
Days moths lived after egg deposition	3.18	7	1
Days moths lived	12.1	17	8

The moths were confined in common jelly glasses with perforated tin covers. A fresh pear leaf was inserted for egg deposition, and food was given in the form of dilute sugar and honey solution placed on a small piece of sponge. Most of the eggs were laid on the leaves, though a few were invariably also found on the glass.

Judging from the records of emergence of moths and their habits as observed above, it becomes evident that the earliest eggs from this brood were laid about August 3. The height of the egg deposition period should have been September 1, and the close of the period September 15.

Length of life of moths.—A record on the length of the life of the summer moths in the so-called stock jars was taken on 445 individuals (Tables XX and XXI). These moths were kept under similar conditions to those of the spring brood.

TABLE XX.—*Length of life of moths of the first brood, in confinement, Douglas, Mich., 1910.*

Number.	Length of life.	Number.	Length of life.	Number.	Length of life.	Number.	Length of life.
	Days.		*Days.*		*Days.*		*Days.*
5	2	70	7	39	12	9	17
15	3	49	8	27	13	4	18
14	4	56	9	18	14	2	19
34	5	27	10	5	15	2	20
41	6	23	11	4	16	1	24

Total number of moths, 445.

TABLE XXI.—*Length of life of moths of the first brood in confinement, Douglas, Mich., 1910; summary of Table XX.*

Observations.	Length of life.
	Days.
Average	8.93
Maximum	24
Minimum	2

The results of observations on the length of life for the two broods of moths are practically the same (compare Tables XI and XXI).

LIFE CYCLE OF THE FIRST GENERATION.

In the preceding pages the separate stages of the first generation have been considered at length, and the length of time of the development has been determined by a number of experiments for each stage. The final figures from these records thus represent the average life cycle of the codling moth of the first generation.

	Days.
Incubation period of eggs	6
Length of feeding of larvæ	25
Time of larvæ in cocoons	7
Length of pupal stage	13.6
Total	51.6

To test the accuracy of the various experiments for the separate stages an additional experiment was undertaken in which a number of individual insects were carried through from the time of hatching to the emergence of the moths.

TABLE XXII.—*Length of life cycle of the first generation, as determined by rearing in 1910 at Douglas, Mich.*

No. of individual.	Date of— Egg deposition.	Hatching.	Leaving the fruit.	Pupation.	Emergence.	Days— Incubation.	Feeding of— Transforming larvæ.	Wintering larvæ.	In cocoon as larva.	Pupal stage.	Total life cycle.
1	June 25	July 2	July 26	July 31	Aug. 15	7	24	......	5	15	51
2	...do....	...do.....	July 28	....	....	7	......	26	......	......	......
3	...do.....	...do.....	July 29	Aug. 2	Aug. 18	7	27	......	4	16	54
4	...do.....	...do.....	July 30	....	....	7	......	28	......	......	......
5	...do.....	...do.....	...do.....	Aug. 8	Aug. 23	7	28	......	9	15	59
6	...do.....	...do.....	July 31	Aug. 9	...do.....	7	29	......	9	14	59
7	...do.....	...do.....	Aug. 1	....	....	7	......	30	......	......	......
8	June 28	July 4	July 24	July 29	Aug. 13	6	20	......	5	15	46
9	...do.....	...do.....	...do.....	...do.....	...do.....	6	20	......	5	15	46
10	...do.....	...do.....	July 26	July 31	Aug. 16	6	22	......	5	16	49
11	...do.....	...do.....	July 27	Aug. 2	Aug. 18	6	23	......	6	16	51
12	...do.....	...do.....	...do.....	...do.....	Aug. 20	6	23	......	6	18	53
13	...do.....	...do.....	...do.....	...do.....	Aug. 15	6	23	......	6	13	48
14	...do.....	...do.....	July 28	....	....	6	......	24	......	......	......
15	...do.....	...do.....	July 30	....	....	6	......	26	......	......	......
16	June 30	...do.....	July 23	July 27	Aug. 12	6	17	......	4	16	43
17	...do.....	July 6	July 29	....	....	6	......	23	......	......	......
18	...do.....	...do.....	July 30	....	....	6	......	24	......	......	......
19	...do.....	...do.....	Aug. 1	....	....	6	......	26	......	......	......
20	...do.....	...do.....	Aug. 2	Aug. 6	Aug. 20	6	27	......	4	14	51
21	...do.....	...do.....	...do.....	Aug. 12	Aug. 24	6	27	......	10	12	55
22	...do.....	...do.....	Aug. 3	....	....	6	......	28	......	......	......
23	...do.....	...do.....	Aug. 4	....	....	6	......	29	......	......	......
24	...do.....	...do.....	Aug. 6	Aug. 17	Sept. 1	6	31	......	11	15	63
25	...do.....	...do.....	...do.....	....	....	6	......	31	......	......	......
26	July 1	July 8	July 25	....	....	7	......	17	......	......	......
27	...do.....	...do.....	July 28	....	....	7	......	20	......	......	......
28	...do.....	...do.....	Aug. 2	Aug. 4	Aug. 18	7	25	......	2	14	48
29	...do.....	...do.....	...do.....	...do.....	Aug. 19	7	25	......	2	15	49
30	...do.....	...do.....	...do.....	Aug. 9	Aug. 23	7	25	......	7	14	53
31	...do.....	...do.....	Aug. 3	....	....	7	......	26	......	......	......
32	...do.....	...do.....	Aug. 4	....	....	7	......	27	......	......	......
33	...do.....	...do.....	Aug. 5	....	....	7	......	28	......	......	......
34	...do.....	...do.....	Aug. 6	....	....	7	......	29	......	......	......
35	...do.....	...do.....	Aug. 9	....	....	7	......	32	......	......	......
36	...do.....	...do.....	Aug. 13	....	....	7	......	36	......	......	......
37	...do.....	...do.....	Aug. 22	....	....	7	......	45	......	......	......
38	July 5	July 11	Aug. 3	....	....	6	......	23	......	......	......
39	...do.....	...do.....	Aug. 4	Aug. 12	Aug. 25	6	24	......	8	13	51
40	...do.....	...do.....	Aug. 6	Aug. 13	Aug. 26	6	26	......	7	13	52
41	...do.....	...do.....	Aug. 8	...do.....	Aug. 25	6	28	......	5	12	51
42	...do.....	...do.....	Aug. 9	...do.....	....	6	......	29	4	......	......
43	...do.....	...do.....	Aug. 13	....	....	6	......	33	......	......	......
44	July 7	July 13	Aug. 12	....	....	6	......	30	......	......	......
45	...do.....	...do.....	...do.....	....	....	6	......	30	......	......	......
46	...do.....	...do.....	Aug. 13	....	....	6	......	31	......	......	......
47	...do.....	...do.....	...do.....	....	....	6	......	31	......	......	......
48	...do.....	...do.....	...do.....	....	....	6	......	31	......	......	......
49	...do.....	...do.....	Aug. 15	....	....	6	......	33	......	......	......
50	...do.....	...do.....	Aug. 17	....	....	6	......	35	......	......	......
51	...do.....	...do.....	...do.....	....	....	6	......	35	......	......	......

TABLE XXIII.—*Life cycle of the first generation; summary of Table XXII.*

	Incubation.	Feeding of— Transforming larvæ.	Wintering larvæ.	In cocoon as larva.	Pupal stage.	Total life cycle.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Average..............................	6.37	24.7	28.9	6.0	14.5	51.5
Maximum..............................	7	31	45	11	18	63
Minimum..............................	6	17	....	2	12	43

The results of these experiments are given in Tables XXII and XXIII. Although limited in number the results of these experiments agree very closely with those of the previous experiments for the separate stages, namely, the life-cycle experiments averaged 51.5 days,

and the final average for the various experiments on separate stages averaged 51.6 days.

The wintering larvæ of the first brood, which complete their life cycle the following spring, have not been included in the consideration of the life cycle of the first generation.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation.—On an average the second brood of eggs (Tables XXIV and XXV) required 7.5 days for hatching, which is one day longer than was found necessary for those of the first brood. The maximum length of time for incubation was 11 days, the minimum 6 days. The red ring became first visible from three to four days after egg deposition and the black spot two days before hatching.

TABLE XXIV.—*Length of incubation of the second brood of eggs laid in rearing cages, Douglas, Mich., 1910.*

No. of observation.	Date of— Egg deposition.	Appearance of red ring.	Appearance of black spot.	Hatching.	Duration of— Red ring.	Black spot.	Incubation.
					Days.	*Days.*	*Days.*
1	Aug. 2	Aug. 5	Aug. 10	Aug. 12	3	8	10
2	...do.....	...do.....	...do.....	Aug. 13	3	8	11
3	Aug. 3	...do.....	Aug. 9	Aug. 11	2	6	8
4	Aug. 4	Aug. 10	Aug. 11	Aug. 13	6	7	9
5	...do.....	...do.....	...do.....	Aug. 14	6	7	10
6	Aug. 6	....	....	...do.....	....	....	8
7	Aug. 7	Aug. 12	Aug. 14	Aug. 15	5	7	8
8	...do.....	...do.....	...do.....	Aug. 16	5	7	9
9	Aug. 8	Aug. 13	...do.....	Aug. 15	5	6	7
10	...do.....	...do.....	...do.....	Aug. 16	5	6	8
11	Aug. 9	Aug. 12	...do.....	...do.....	3	5	7
12	...do.....	...do.....	...do.....	Aug. 17	3	5	8
13	Aug. 10	Aug. 14	Aug. 16	...do.....	4	6	7
14	Aug. 11	...do.....	...do.....	...do.....	3	5	6
15	...do.....	...do.....	...do.....	Aug. 18	3	5	7
16	Aug. 12	Aug. 15	Aug. 17	...do.....	3	5	6
17	...do.....	...do.....	...do.....	Aug. 19	3	5	7
18	Aug. 13	Aug. 16	Aug. 18	...do.....	3	5	6
19	...do.....	...do.....	...do.....	Aug. 20	3	5	7
20	Aug. 14	...do.....	...do.....	...do.....	2	4	6
21	Aug. 15	Aug. 17	Aug. 19	Aug. 21	2	4	6
22	...do.....	...do.....	...do.....	Aug. 22	2	4	7
23	Aug. 16	Aug. 18	Aug. 21	...do.....	2	5	6
24	...do.....	...do.....	...do.....	Aug. 23	2	5	7
25	Aug. 17	Aug. 19	...do.....	...do.....	2	4	6
26	...do.....	...do.....	...do.....	Aug. 24	2	4	7
27	Aug. 18	Aug. 21	Aug. 23	...do.....	3	5	6
28	Aug. 19	Aug. 22	Aug. 24	Aug. 25	3	5	6
29	Aug. 20	Aug. 23	Aug. 25	Aug. 27	3	5	7
30	Aug. 21	...do.....	...do.....	...do.....	2	4	6
31	...do.....	...do.....	...do.....	Aug. 28	2	4	7
32	Aug. 22	Aug. 25	Aug. 27	...do.....	3	5	6
33	...do.....	...do.....	...do.....	Aug. 29	3	5	7
34	Aug. 23	Aug. 26	Aug. 28	...do.....	3	5	6
35	...do.....	...do.....	...do.....	Aug. 30	3	5	7
36	Aug. 24	Aug. 27	Aug. 29	...do.....	3	5	6
37	...do.....	...do.....	...do.....	Aug. 31	3	5	7
38	Aug. 25	Aug. 29	Aug. 31	Sept. 2	4	6	8
39	...do.....	...do.....	...do.....	Sept. 3	4	6	9
40	Aug. 26	Aug. 30	Sept. 1	...do.....	4	6	8
41	...do.....	...do.....	...do.....	Sept. 4	4	6	9
42	Aug. 28	Sept. 2	Sept. 4	Sept. 5	5	7	8
43	...do.....	...do.....	...do.....	Sept. 6	5	7	9
44	...do.....	...do.....	...do.....	Sept. 7	5	7	10
45	Aug. 29	Sept. 3	Sept. 5	Sept. 6	5	7	8
46	...do.....	...do.....	...do.....	Sept. 7	5	7	9
Average					3.4	5.5	7.4
Maximum					6	8	11
Minimum					2	4	6

TABLE XXV.—*Incubation period of eggs of the second brood in rearing cages, Douglas, Mich., 1910; summary of Table XXIV.*

Appearance of red ring.		Appearance of black spot.		Total incubation period.	
Number of days.	Number of observations.	Number of days.	Number of observations.	Number of days.	Number of observations.
2	10	4	7	6	13
3	19	5	19	7	14
4	5	6	8	8	9
5	9	7	9	9	6
6	2	8	2	10	3
......	......	......	......	11	1

SECOND BROOD OF LARVÆ.

Time of hatching.—The time of hatching of second-brood larvæ under orchard conditions has been determined by methods described on page 14 for the first brood. A maximum abundance of newly hatched larvæ occurred about September 10. The earliest larva of the brood hatched August 12. In the cages several late-deposited eggs failed to hatch, and it is possible that eggs in the field at this time would likewise remain undeveloped.

TABLE XXVI.—*Length of feeding of second-brood larvæ, Douglas, Mich., 1910.*

No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days of feeding.
1	Aug. 15	Sept. 12	28	28	Aug. 19	Oct. 1	43	55	Aug. 24	Oct. 1	38
2	...do.....	Sept. 13	29	29	Aug. 20	Sept. 24	35	56	...do.....	...do.....	38
3	...do.....	...do.....	29	30	...do.....	...do.....	35	57	...do.....	Oct. 2	39
4	...do.....	...do.....	29	31	Aug. 21	Sept. 15	25	58	...do.....	...do.....	39
5	...do.....	Sept. 15	31	32	...do.....	Sept. 20	30	59	Aug. 25	Sept. 15	21
6	Aug. 17	Sept. 20	34	33	...do.....	Sept. 21	31	60	...do.....	Sept. 27	33
7	...do.....	Sept. 24	38	34	...do.....	Sept. 22	32	61	...do.....	Oct. 1	37
8	...do.....	...do.....	38	35	...do.....	Sept. 23	33	62	Aug. 26	Oct. 2	37
9	...do.....	Oct. 1	45	36	...do.....	Sept. 24	34	63	...do.....	Oct. 3	38
10	Aug. 18	Sept. 23	36	37	Aug. 22	Sept. 12	21	64	...do.....	...do.....	38
11	...do.....	Sept. 24	37	38	...do.....	...do.....	21	65	...do.....	Oct. 7	42
12	...do.....	...do.....	37	39	...do.....	Sept. 23	32	66	Aug. 28	Sept. 24	27
13	...do.....	Sept. 28	41	40	...do.....	...do.....	32	67	...do.....	Oct. 3	36
14	...do.....	Oct. 1	44	41	...do.....	...do.....	32	68	...do.....	...do.....	36
15	Aug. 19	Sept. 12	24	42	...do.....	Sept. 26	35	69	...do.....	...do.....	36
16	...do.....	...do.....	24	43	Aug. 23	Sept. 23	31	70	...do.....	Oct. 4	37
17	...do.....	Sept. 15	27	44	...do.....	...do.....	31	71	...do.....	...do.....	37
18	...do.....	...do.....	27	45	...do.....	Oct. 1	39	72	...do.....	Oct. 6	39
19	...do.....	Sept. 20	32	46	...do.....	...do.....	39	73	...do.....	...do.....	39
20	...do.....	...do.....	32	47	...do.....	Oct. 3	41	74	Aug. 29	Oct. 10	42
21	...do.....	...do.....	32	48	Aug. 24	Sept. 21	28	75	Aug. 30	Sept. 25	26
22	...do.....	Oct. 1	43	49	...do.....	Sept. 23	30	76	...do.....	Sept. 29	30
23	...do.....	...do.....	43	50	...do.....	...do.....	30	77	Aug. 31	Oct. 4	34
24	...do.....	...do.....	43	51	...do.....	Sept. 24	31	78	...do.....	Oct. 6	36
25	...do.....	...do.....	43	52	...do.....	Sept. 25	32	79	...do.....	...do.....	36
26	...do.....	...do.....	43	53	...do.....	...do.....	32	80	Sept. 3	Oct. 1	28
27	...do.....	...do.....	43	54	...do.....	...do.....	32	81	Sept. 4	Oct. 6	32
Average											34.2
Maximum											45
Minimum											21

TABLE XXVII.—*Feeding period of second-brood larvæ; summary of Table XXVI.*

Number of observations.	Days of feeding.	Number of observations.	Days of feeding.	Number of observations.	Days of feeding.
3	21	5	31	6	39
2	24	11	32	2	41
1	25	2	33	2	42
1	26	3	34	7	43
3	27	3	35	1	44
3	28	6	36	1	45
3	29	6	37		
4	30	6	38	81	2,770

Length of feeding period.—In Table XXVI will be found the records on the feeding periods for 81 individual larvæ of the second brood. The average length of feeding for the total number of observations is 34.2 days, the maximum 45 days, and the minimum 21 days. As is to be expected these results are much higher than those for the first brood (compare with Table XXIII), since at this time of year a much lower degree of temperature prevails, and more feeding may be necessary for the hibernating larvæ. Figure 8 (p. 26) shows the jar used in the rearing of codling moth larvæ.

Time of leaving the fruit.—The Saugatuck band-record experiment of figure 10 shows that the earliest mature larvæ appeared under the bands August 30, and that larvæ were collected more or less abundantly throughout September and the early part of October. The almost total absence of larvæ during November was to a large extent due to the scarcity of fruit, and this condition materially limited the number of second-brood larvæ.

TABLE XXVIII.—*Band-record experiments, Saugatuck, Mich., 1910.*

No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.	No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.
1	July 13	6	5	.....	.....	.....	1	21	Sept. 12	13	.....	.....	11	1	1
2	July 17	41	34	.....	.....	.....	7	22	Sept. 15	18	.....	.....	15	3	0
3	July 20	28	10	.....	1	.....	17	23	Sept. 18	19	.....	.....	9	3	7
4	July 23	34	19	1	1	.....	13	24	Sept. 21	[1] 26	.....	.....	6	2	[1] 18
5	July 26	54	26	2	5	1	20	25	Sept. 24	16	.....	.....	11	.....	5
6	July 29	35	21	1	2	1	10	26	Sept. 27	10	.....	.....	6	1	3
7	Aug. 1	58	33	2	3	.....	20	27	Sept. 30	7	.....	.....	5	2	0
8	Aug. 4	54	30	1	8	1	14	28	Oct. 3	22	.....	.....	19	.....	3
9	Aug. 7	49	13	1	18	.....	17	29	Oct. 6	13	.....	.....	9	1	3
10	Aug. 10	27	8	.....	18	.....	1	30	Oct. 9	3	.....	.....	1	2	0
11	Aug. 13	35	2	.....	25	.....	8	31	Oct. 12	9	.....	.....	9	.....	0
12	Aug. 16	32	.....	.....	24	.....	8	32	Oct. 15	11	.....	.....	5	.....	6
13	Aug. 19	23	.....	.....	17	.....	6	33	Oct. 18	8	.....	.....	5	.....	3
14	Aug. 22	35	.....	.....	28	.....	7	34	Oct. 21	5	.....	.....	3	1	1
15	Aug. 25	23	.....	.....	9	1	13	35	Oct. 24	3	.....	.....	2	.....	1
16	Aug. 28	14	.....	.....	9	2	3	36	Oct. 28	2	.....	.....	.....	.....	2
17	Sept. 1	21	.....	.....	11	1	9	37	Oct. 30	0	.....	.....	.....	.....	0
18	Sept. 3	8	.....	.....	6	2	.....	38	Nov. 2	2	.....	.....	.....	.....	1
19	Sept. 6	7	.....	.....	4	.....	3								
20	Sept. 9	17	.....	.....	7	4	6		Total.	788	201	8	313	29	237

[1] 12 larvæ escaped.

BAND RECORDS OF 1910.

The band-record experiments form a very important part in the study of the life history of the codling moth, and constitute at present the only safe test of the development of the insect under natural

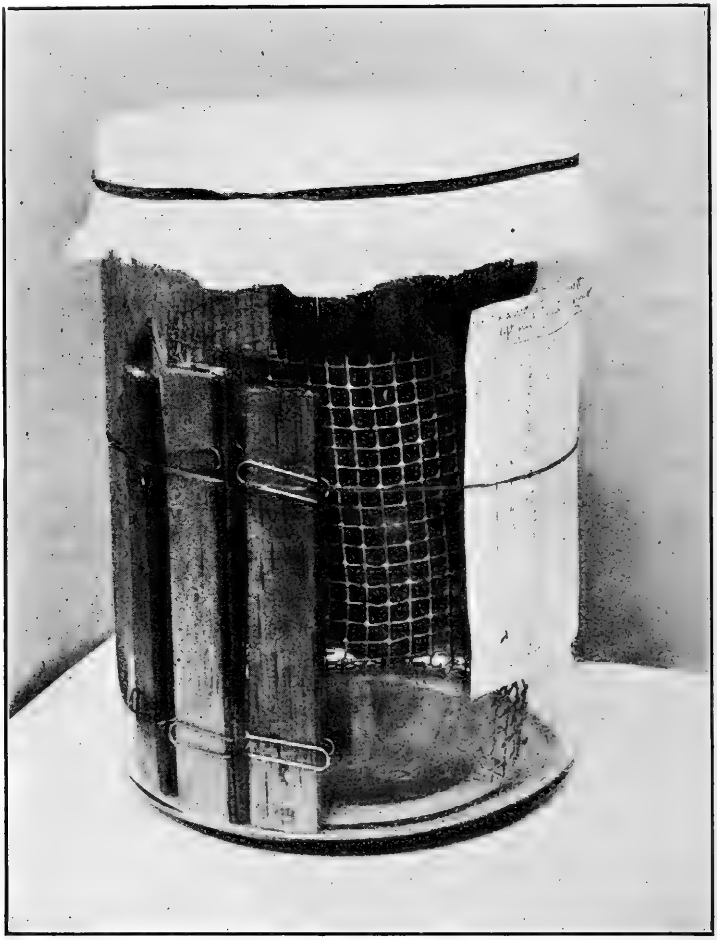


FIG. 8.—Cage used in determining feeding period of codling-moth larvæ. (Original.)

conditions. When carefully carried out these experiments furnish indispensable data on the relative abundance of the first and second broods of larvæ, time of emergence of moths, parasitism, hibernation, etc. (see Table XXXI), and yield in addition an abundance of material for laboratory rearing experiments.

TABLE XXIX.—*Lake Shore band-record experiments, Douglas, Mich., 1910.*

No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.	No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.
1	July 12	18	17	1	....	....	....	23	Sept. 16	18	....	....	8	1	9
2	July 15	30	22	....	....	....	8	24	Sept. 19	15	....	....	8	3	4
3	July 18	40	28	2	....	....	10	25	Sept. 22	8	....	....	3	....	5
4	July 21	31	17	4	....	....	10	26	Sept. 25	14	....	....	2	3	9
5	July 24	45	27	4	....	....	14	27	Sept. 28	7	....	....	2	....	5
6	July 27	75	45	7	4	1	18	28	Oct. 1	9	....	....	6	1	2
7	July 30	51	35	2	8	1	5	29	Oct. 4	1	....	....	1	....	0
8	Aug. 2	42	28	5	7	....	2	30	Oct. 7	5	....	....	4	1	0
9	Aug. 5	59	25	4	22	1	7	31	Oct. 10	0	....	....	....	....	0
10	Aug. 8	59	8	1	20	5	25	32	Oct. 13	3	....	....	1	....	2
11	Aug. 11	59	9	....	29	4	17	33	Oct. 16	1	....	....	....	....	1
12	Aug. 14	66	1	....	41	4	20	34	Oct. 19	4	....	....	....	....	4
13	Aug. 17	69	....	....	46	2	21	35	Oct. 22	....	....	....	....	....	0
14	Aug. 20	50	....	....	37	1	12	36	Oct. 25	....	....	....	....	....	0
15	Aug. 23	42	....	....	36	1	5	37	Oct. 29	2	....	....	....	....	2
16	Aug. 25	40	....	....	23	2	15	38	Oct. 31	....	....	....	....	....	0
17	Aug. 29	22	....	....	11	....	11	39	Nov. 3	1	....	....	....	....	1
18	Sept. 1	27	....	....	16	3	8	40	Nov. 6	....	....	....	....	....	0
19	Sept. 4	24	....	....	15	3	6	41	Nov. 9	2	....	....	....	....	2
20	Sept. 7	11	....	....	9	1	1								
21	Sept. 10	16	....	....	9	3	4		Total	985	262	30	377	45	271
22	Sept. 13	19	....	....	9	4	6								

In 1910, band-record experiments were placed in three separate orchards, located several miles apart, for the purpose of establishing better average results and determining as far as possible the extent of existing variation in the time of development of the codling moth in the selected localities. These were chosen in regard to their relative proximity to Lake Michigan, one near the lake, one 2 miles east, and the other 7 miles east of the lake. The influence of the lake upon the temperature over the fruit belt of the western part of Michigan is well known by the local fruit growers and horticulturists and is strikingly shown by the difference in the period of blossoming of apples. This period is much earlier in orchards situated inland and later in orchards near the lake. It should therefore be expected that the codling moth is influenced in its development to a similar extent.

TABLE XXX.—*Band-record experiment at New Richmond, Mich., in 1910; larvæ collected by Mr. Herman Schultz.*

No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.	No. of record.	Date of collecting.	No. of larvæ.	No. of moths, 1910.	No. of parasites, 1910.	No. of moths, 1911.	No. of parasites, 1911.	Total number of dead larvæ.
1	July 11	29	12	3	....	....	14	16	Aug. 25	2	....	....	1	....	1
2	July 14	55	27	2	....	....	26	17	Aug. 28	8	....	....	6	1	1
3	July 17	69	20	7	2	....	40	18	Aug. 31	1	....	....	0	1	0
4	July 20	57	24	4	11	....	18	19	Sept. 3	9	....	....	6	1	2
5	July 23	50	21	3	6	....	20	20	Sept. 6	7	....	....	3	....	4
6	July 26	50	17	8	6	....	19	21	Sept. 9	7	....	....	4	1	2
7	July 29	33	9	4	4	....	16	22	Sept. 12	10	....	....	5	....	5
8	Aug. 1	38	17	1	11	1	8	23	Sept. 15	[1] 5	....	....	1	....	0
9	Aug. 4	22	3	....	11	....	8	24	Sept. 18	10	....	....	3	1	6
10	Aug. 7	15	2	....	10	1	2	25	Sept. 21	6	....	....	2	2	2
11	Aug. 10	15	1	....	11	....	3	26	Sept. 24	3	....	....	2	....	1
12	Aug. 13	15	....	....	11	....	4	27	Sept. 27	5	....	....	3	1	1
13	Aug. 16	7	....	....	5	....	2	28	Sept. 30	1	....	....	0	....	1
14	Aug. 19	5	....	....	4	....	1								
15	Aug. 22	9	....	....	9	....	0			543	153	32	137	10	207

[1] 4 larvæ escaped.

The three band records have been referred to as the Lake Shore experiments located near the shore of the lake southwest of Douglas; the Saugatuck experiments, 2 miles from the lake and northeast of Saugatuck, and the New Richmond experiments, near the village of the same name, 7 miles from the lake. Of these the Saugatuck experiments represented closely the locality of the field station and

FIG. 9.—Burlap bands on an apple tree, to catch codling-moth larvæ. (Original.)

the results from these last band records have been used to supplement the laboratory rearing experiments.[1] Practically all of the apple trees used in these experiments were old and badly neglected, and none of the trees had for some time been sprayed with a poison spray, so that the codling moth had for years developed normally and unchecked in the above orchards.

[1] During 1909 and 1911 the band-record experiments, which in 1910 were interrupted on account of the absence of fruit during that season, were carried out in the orchard on the grounds of the station.

Whenever possible, winter varieties of apples have been used for the band records to test the extent of infestation of the second-brood larvæ. This was not entirely possible in case of the Lake Shore and the New Richmond experiments because of the great scarcity of fruit during 1910, so that in these localities summer and fall varieties were used, in addition to winter varieties. The apple trees of the Saugatuck band experiments consisted of the following varieties: Three Baldwin trees, one Greening tree, two Golden Russet trees, and one crabapple tree. Through the courtesy of Mr. Herman Schultz, of East Saugatuck, Mich., five of these trees were placed free of charge at the disposal of the station.

The apple trees were prepared for the band experiment in the usual way. The loose and rough bark was scraped off from the trunk and main branches. Cracks and crevices and decayed hollows in the trees were plastered over with cement. A considerable amount of dead wood had to be removed from several of the trees before these could be used. A 4-ply burlap band about 5 inches wide was placed around the trunk of each tree and about 2 feet from the ground. Sometimes it was necessary to place additional bands around the main branches on badly damaged trees (fig. 9), but as a rule a single band was found to be sufficient.

The bands were examined every three days and the larvæ collected from each orchard were brought to the laboratory for further observations. The details pertaining to these records will be found in Tables XXVIII to XXXI.

TABLE XXXI.—*Summary of Lake Shore, Saugatuck, and New Richmond, Mich., band record experiments of 1910.*

Observations.	Lake Shore.		Saugatuck.		New Richmond.	
	Total.	Per cent.	Total.	Per cent.	Total.	Per cent.
Larvæ collected from bands	985	100.0	788	100.0	543	100.0
Moths emerging:						
1910	262	41.0	201	25.5	153	28.2
1911	377	59.0	313	39.7	137	25.2
1910–1911	639	64.8	514	65.2	290	53.4
Parasitized larvæ	75	7.6	37	4.7	42	7.7
Winter-killed and injured larvæ	271	27.5	237	30.1	207	38.1
Larvæ of the first brood	860	87.3	577	73.2	479	88.2
Transforming larvæ of the first brood	262	30.5	201	34.8	153	31.9
Wintering larvæ of the first brood	598	69.5	376	65.2	326	68.1
Larvæ of the second brood	125	12.7	211	26.8	64	11.8

On examining the curves of figure 10, showing the results of the band experiments, it will be noted that the two broods of larvæ overlap and can not be definitely determined from these experiments alone. With special reference to the Saugatuck experiments the hypothetical curves in figure 10 which have been drawn to represent the two broods are based on the following considerations: The

last moth of the spring brood emerged July 27; it required at that time of the season 45 days from the date of emergence of the moth to time of maturity of the resulting larva. Thus the larvæ of the first brood must have ceased to appear by September 10. The first moth of the first brood or summer moth emerged July 29, at which time the insect developed rapidly and mature larvæ resulted in 33

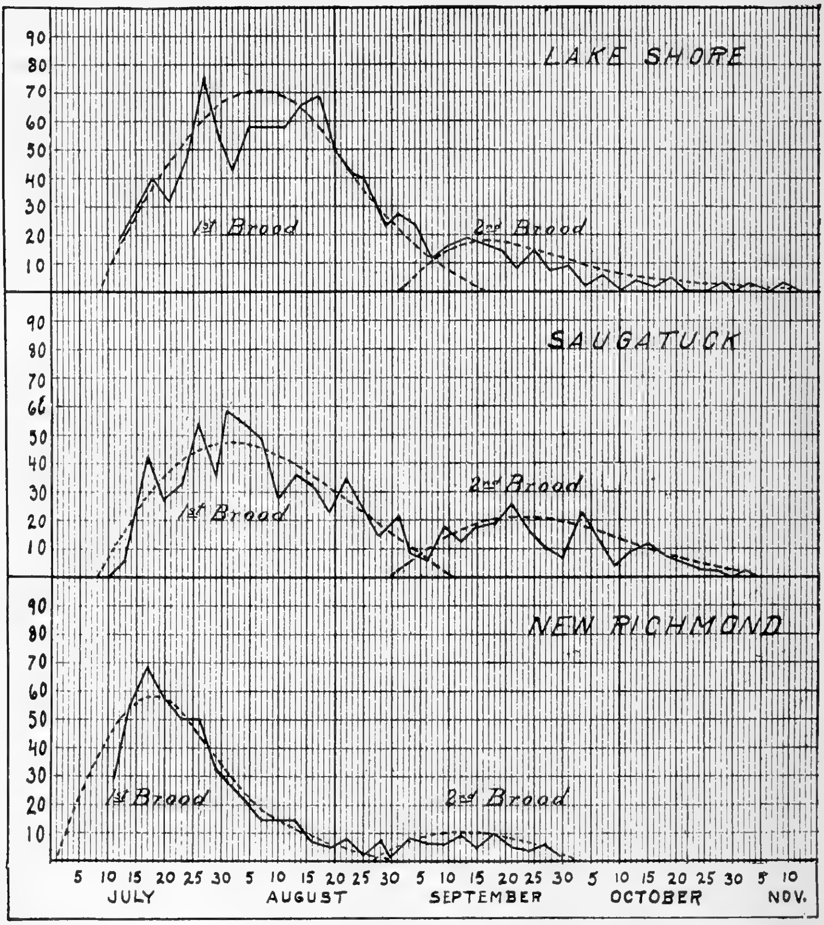


FIG. 10.—Curves made from band-record experiments in orchards at the lake shore near Douglas, at Saugatuck, and at New Richmond, Mich., 1910. (Original.)

days. Thus the first larvæ of the second brood appeared August 31. Similarly, the first-brood and second-brood larvæ in the Lake Shore and New Richmond experiments have been determined, with due consideration given to the seasonal conditions of each locality.

The results from three band experiments may be appreciated by an examination of the curves in figure 10. A difference in the time and rate of maturity of larvæ will be noted in considering the height of the curves representing the first brood. In the Lake Shore orchard

the maximum occurred August 8, in the Saugutuck orchard July 31, and in the New Richmond orchard July 18. It will not be possible to compare the dates for the appearance of first larvæ of the first brood, since the New Richmond experiments commenced slightly after the larvæ began to appear.

At the Lake Shore band experiments larvæ were collected in great numbers during the month of August, whereas at New Richmond only a few were obtained. There is only a slight difference in the time of appearance of the earliest second-brood larvæ in these localities, which would indicate the existence of a tendency on the part of the seasonal conditions to become equalized or uniform over the fruit belt at midsummer. At the Lake Shore orchard larvæ continued to appear one month later than in the New Richmond orchard. Part of this difference was due to the scarcity of fruit at New Richmond, but also partly because of prevailing higher temperature during the fall near the lake, which prolonged the season in the latter locality.[1] Though limited in scope, the results of these band experiments show that the codling moth varies in the time of its development in these three localities in close relation to existing climatic conditions, thus indicating that the insect must be governed by the same climatic conditions that govern the plants, and it must be due to this fact that we find a corresponding difference in the time of activity of the insect in the spring, as is noted in the time of blossoming of apples in the different sections of the fruit belt.

Of the total number of larvæ of the Saugatuck band experiment 73.2 per cent pertained to the first brood and 26.8 per cent to the second brood. Of the first-brood larvæ 34.8 per cent transformed the same season, and 65.2 per cent wintered in the larval stage. Of the total number of larvæ, 25.5 per cent developed into moths in 1910 and 39.7 per cent in 1911. Parasitism by *Ascogaster carpocapsæ* affected 4.7 per cent, and 30.1 per cent died during the winter, killed by cold.

SUMMARY OF SEASONAL-HISTORY STUDIES OF 1910.

Figure 11 represents graphically the main results of the seasonal-history studies of 1910 and can better be appreciated from the diagram than by description.

Except for the prolonged pupal period during the very abnormal spring of 1910 the insect developed fairly normally so that from the point of view of the activities of the codling moth the season may be taken to have been about average.

[1] For a more thorough test, records should be taken on temperature, time of blossoming of apples, and time of emergence of spring brood of moths in the different sections in the fruit belt.

SEASONAL-HISTORY STUDIES OF 1911.

The results of the 1911 life-history studies of the codling moth are in many respects similar to those obtained during the previous year.

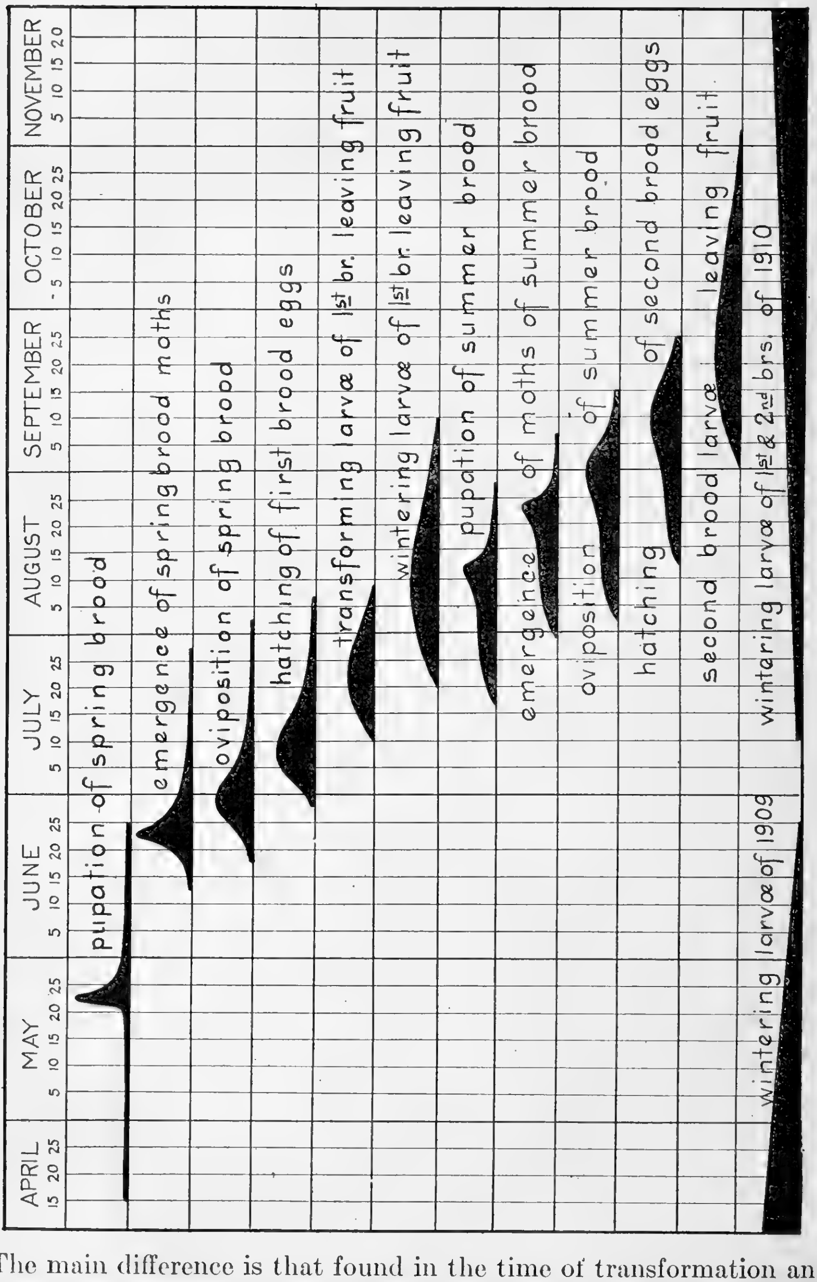


FIG. 11.—Diagram to illustrate seasonal history of the codling moth as observed during 1910, at Douglas Mich. (Original.)

The main difference is that found in the time of transformation and date of appearance of the different stages, which is ascribed to the prevalence of a very unusually high temperature during the spring

and summer. To a certain extent the 1911 life-history studies constitute a test upon the 1910 investigation and in addition show the behavior of the codling moth under the above climatic conditions.

In the presentation of the observations made during 1911 on the codling moth the same plan has been followed as for 1910, and many of the details concerning methods and tabulation previously described apply equally to the 1911 studies.

TABLE XXXII.—*Time of pupation in the spring of 1911.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
May 9	1	May 22	10	June 2	2	June 14	3
May 11	1	May 23	8	June 3	2	June 15	1
May 12	1	May 24	8	June 4	3	June 16	1
May 14	6	May 25	7	June 5	5	June 17	3
May 15	7	May 26	5	June 6	4	June 19	2
May 16	2	May 27	8	June 7	2	June 21	1
May 17	8	May 28	9	June 8	2	June 22	1
May 18	12	May 29	6	June 9	7	June 26	1
May 19	16	May 30	7	June 10	6		
May 20	14	May 31	11	June 11	4		
May 21	11	June 1	3	June 13	1		

Total pupæ, 212.

SOURCE OF REARING MATERIAL.

The rearing material in the spring of 1911 consisted of wintering larvæ, which in a normal way had entered hibernation the previous season. Practically all of the larvæ were from band records and represented the normal proportion of both first-brood and second-brood larvæ. The wintering cocoons were made between narrow strips of wood (fig. 4) and in pieces of corrugated paper (fig. 17). During the winter larvæ were kept in an outdoor shelter.

WINTER-KILLED LARVÆ.

The percentage of larvæ killed by cold during the winter proved to be equally as high during 1911 as observed in 1910. After the completion of the different band-record observations the results show the following percentages of winter-killed larvæ:

	Per cent.
New Richmond band records	38.1
Saugatuck band records	30
Lake Shore band records	27.5

From these figures should be substracted a small number of larvæ injured in the course of transportation from the field to the laboratory. Those from New Richmond showing the highest percentage of mortality were sent in boxes through the mail and suffered more or less under transportation.[1] The larvæ from the Lake Shore and Sauga-

[1] During 1911 an improvement was made in the method of shipping the larvæ from the distant localities of the band records, by the use of mailing tubes (see page 61 and fig. 17).

tuck orchards, however, were all carefully handled, and the results of these observations show approximately the normal proportion of winter-killed larvæ.

SPRING BROOD OF PUPÆ.

Time of pupation.—In the rearing cages pupation commenced on May 9, reached a maximum May 19, and terminated June 26 (Table XXXII). The relative rate of pupation is illustrated by a curve in figure 12. It will here be observed that pupation occurred rather irregularly and that the time when the larger number of individuals pupated extended over a longer period than in 1910. This, of course, had a direct bearing upon the time and rate of emergence of the moths of the spring brood, which, like the pupæ, appeared very irregularly.

TABLE XXXIII.—*Length of pupal stages of the spring brood, Douglas, Mich., 1911.*

No.	Pupated.	Emerged.	Days.	No.	Pupated.	Emerged.	Days.	No.	Pupated.	Emerged.	Days.
1	May 14	May 29	15	42	May 21	June 10	20	83	May 29	June 19	21
2	...do.....	...do.....	15	43	...do.....	June 9	19	84	...do.....	...do.....	21
3	...do.....	May 30	16	44	...do.....	June 10	20	85	May 30	June 20	21
4	May 15	May 28	13	45	May 22	June 14	23	86	...do.....	June 18	19
5	...do.....	May 30	15	46	...do.....	June 11	20	87	...do.....	June 19	20
6	May 16	...do.....	14	47	...do.....	June 10	19	88	May 31	June 21	21
7	...do.....	June 6	21	48	...do.....	June 9	18	89	...do.....	...do.....	21
8	May 17	June 2	16	49	...do.....	June 10	19	90	...do.....	June 20	20
9	...do.....	June 3	17	50	May 23	...do.....	18	91	...do.....	June 19	19
10	...do.....	...do.....	17	51	...do.....	...do.....	18	92	...do.....	June 20	20
11	...do.....	June 10	24	52	...do.....	June 11	19	93	June 1	...do.....	19
12	...do.....	June 2	16	53	...do.....	June 10	18	94	June 2	June 22	20
13	May 18	June 3	16	54	May 24	June 6	13	95	...do.....	June 21	19
14	...do.....	...do.....	16	55	...do.....	June 9	16	96	June 3	June 22	19
15	...do.....	June 6	19	56	...do.....	June 10	17	97	...do.....	June 21	18
16	...do.....	June 4	17	57	...do.....	June 11	18	98	June 4	June 23	19
17	...do.....	June 5	18	58	...do.....	June 14	21	99	...do.....	June 24	20
18	...do.....	June 4	17	59	...do.....	June 11	18	100	June 5	June 23	18
19	...do.....	June 5	18	60	May 25	June 12	18	101	...do.....	...do.....	18
20	May 19	June 6	18	61	...do.....	June 14	20	102	...do.....	June 24	19
21	...do.....	June 5	17	62	...do.....	...do.....	20	103	...do.....	...do.....	19
22	...do.....	...do.....	17	63	...do.....	June 12	18	104	June 6	June 23	17
23	...do.....	...do.....	17	64	...do.....	June 14	20	105	...do.....	June 24	18
24	...do.....	...do.....	17	65	...do....	June 12	18	106	June 8	...do.....	16
25	...do.....	June 6	18	66	May 26	June 16	21	107	June 9	June 25	16
26	...do.....	June 4	16	67	...do.....	June 15	20	108	...do.....	June 27	18
27	...do.....	June 5	17	68	...do.....	June 14	19	109	...do.....	June 26	17
28	...do.....	June 6	18	69	...do.....	...do.....	19	110	...do.....	...do.....	17
29	...do.....	June 4	16	70	May 27	June 15	19	111	June 10	...do.....	16
30	...do.....	June 7	19	71	...do.....	June 16	20	112	...do.....	June 27	17
31	...do.....	June 6	18	72	...do.....	June 19	23	113	...do.....	...do.....	17
32	May 20	June 9	20	73	...do.....	June 15	19	114	...do.....	...do.....	17
33	...do.....	June 8	19	74	...do.....	June 16	20	115	June 11	June 30	19
34	...do.....	June 9	20	75	May 28	June 18	21	116	June 13	...do.....	17
35	...do.....	June 8	19	76	...do.....	...do.....	21	117	June 14	...do.....	16
36	...do.....	June 7	18	77	...do.....	...do.....	21	118	...do.....	July 8	24
37	...do.....	June 8	19	78	...do.....	...do.....	21	119	June 15	July 2	17
38	...do.....	...do.....	19	79	...do.....	June 17	20	120	June 17	June 30	13
39	May 21	June 10	20	80	...do.....	June 18	21	121	...do.....	July 2	15
40	...do.....	June 8	18	81	May 29	...do.....	20	122	June 21	July 5	14
41	...do.....	June 10	20	82	...do.....	June 19	21				
Average											18.41
Maximum											24
Minimum											13

Length of pupal stage.—Owing to the very variable climatic conditions during the pupal period there resulted a considerable difference in the length of the pupal stage. The observations for the spring brood extended from May 14 to July 8, during which time records were taken from 122 individual insects.

TABLE XXXIV.—*Length of pupal stages of the spring brood; summary of Table XXXIII.*

Number of observations.	Pupal period.	Number of observations.	Pupal period.	Number of observations.	Pupal period.
	Days.		*Days.*		*Days.*
3	13	18	17	14	21
2	14	22	18	2	23
4	15	23	19	2	24
12	16	20	20		

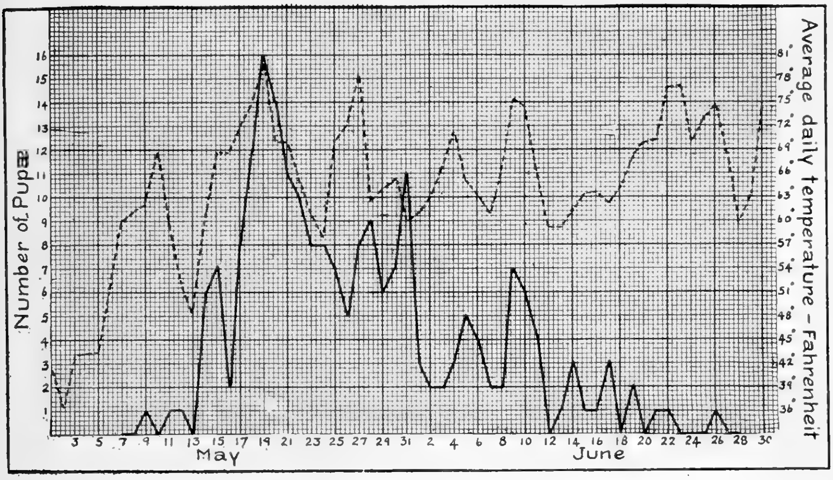


FIG. 12.—Curve of spring pupation of the codling moth in 1911, at Douglas, Mich. (Original.)

The results are given in Table XXXIII and are further summarized in Table XXXIV. The average length of the pupal stage was 18.4 days, the minimum length 13 days, and the maximum 24 days.

Relation of temperature to the duration of the pupal stage.—From general observations it has long been known that the temperature has a marked effect upon the duration of the pupal stage. The intimacy of this relation has already been pointed out by different investigators and most recently by Prof. E. D. Sanderson in a paper on the relation of temperature to the growth of insects.[1]

In our tentative effort to find the existing relation of the temperature to the length of the pupal period at Douglas, Mich., the average temperature has been taken from the average daily temperature

[1] Journ. Econ. Ent., III, p. 113, 1910.

during the pupal stage of a number of individual insects. These averages were computed from the temperature records of Table LXX, which are from a self-recording thermometer of the type used by the United States Weather Bureau. The instrument was regulated in accordance with a mercury thermometer and was kept in the rearing shelter throughout the season. The records in Table XXXIII give the date of pupation and the date of emergence of moths for 122 individual insects.

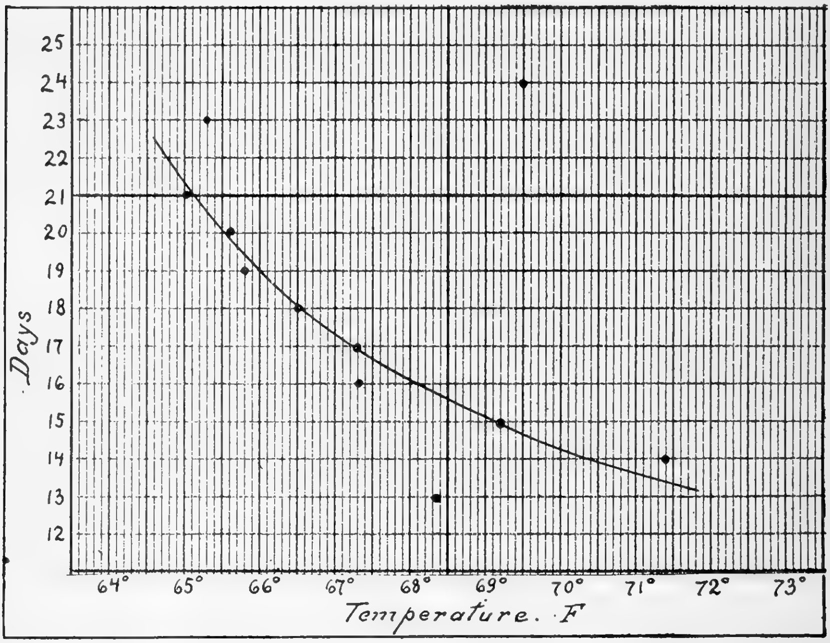


FIG. 13.—Curve showing relation of temperature to the duration of the pupal stage in the spring brood of the codling moth; Douglas, Mich., 1911 (from Table XXXV). (Original.)

TABLE XXXV.—*Average daily temperature during the pupal periods of the spring broods; summary of Table XXXIII.*

Pupal period.	No. of observations.	Average mean temperature.			Pupal period.	No. of observations.	Average mean temperature.		
		Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.
Days.		° *F.*	° *F.*	° *F.*	*Days.*		° *F.*	° *F.*	° *F.*
13	3	68.31	69.86	66.02	19	23	65.84	67.29	64.48
14	2	71.41	73.77	69.06	20	20	65.65	66.81	64.53
15	4	69.19	70.08	68.83	21	14	65.01	67.58	64.49
16	12	67.29	68.56	65.51	23	2	65 33	65.61	65.05
17	18	67.32	69.29	66.06	24	2	69.52	71.73	67.32
18	22	66.50	68.23	65.26					

Observations on the time of transformation were made once daily and invariably in the afternoon. In Table XXXV a summary of these temperature records is given showing the averages for each day and also the number of individual pupæ under observation for the

respective days. To show the extent of variation in results obtained, the maximum and minimum of average temperatures of individual pupal stages are given for the different days in the same table. On examining the diagram of figure 13 it will be noted that where the averages have been made from a large number of observations the results are fairly uniform. These results here show a marked decrease in the time of the pupal stage with an increase of temperature. Considering the curve of this figure we get the following readings:

	°F		°C
For the 15 days pupal stage	69.2	or	20.6
For the 17 days pupal stage	67.3	or	19.6
For the 19 days pupal stage	66.0	or	18.9
For the 21 days pupal stage	65.1	or	18.4

It should be remembered that besides the temperature there are other factors affecting the development of the insects. Moisture and the physical condition of individual insects, etc., naturally tend to cause variation in the length of the pupal stage, and to these factors may be ascribed certain variations in the results obtained.

SPRING BROOD OF MOTHS.

Time of emergence of moths.—The earliest moths, emerging May 26, were about normal in the date of appearance. Subsequently, however, and for the rest of the emergence period, the moths appeared very irregularly and for a longer period than usual. At the height of the emergence, during the middle part of June, two fairly long delays were caused by prevailing rains and a drop of temperature, so that the emergence period, as shown in figure 14, became marked by two distinct maximums. The records for the emergence of 1,127 moths are given in Table XXXVI. The first moth of the summer brood emerged July 7 and the last moth of the spring brood emerged July 8, thus causing the emergence periods of the two broods to overlap.

TABLE XXXVI.—*Time of emergence of moths of the spring brood, Douglas, Mich., 1911.*

Date of emergence.	Total emergence.	Date of emergence.	Total emergence.	Date of emergence.	Total emergence.	Date of emergence.	Total emergence.
May 25	....	June 6	47	June 18	44	June 30	16
May 26	1	June 7	30	June 19	53	July 1	7
May 27	11	June 8	68	June 20	44	July 2	7
May 28	6	June 9	52	June 21	41	July 3	2
May 29	19	June 10	62	June 22	54	July 4	1
May 30	12	June 11	35	June 23	56	July 5	10
May 31	10	June 12	20	June 24	45	July 6	....
June 1	3	June 13	2	June 25	23	July 7	....
June 2	29	June 14	48	June 26	37	July 8	1
June 3	49	June 15	20	June 27	22		
June 4	49	June 16	16	June 28	4		
June 5	43	June 17	15	June 29	13		

Total, 1,127 moths.

Egg deposition by individual moths.—Already during 1910 several experiments had been made to determine the number of eggs deposited by a single female. The results from these observations were, however, limited to a few females and could not be considered conclusive. Further efforts were therefore made in 1911 to obtain additional data on this question. Many difficulties have been encountered in getting moths that will oviposit in captivity. The obstacles have probably

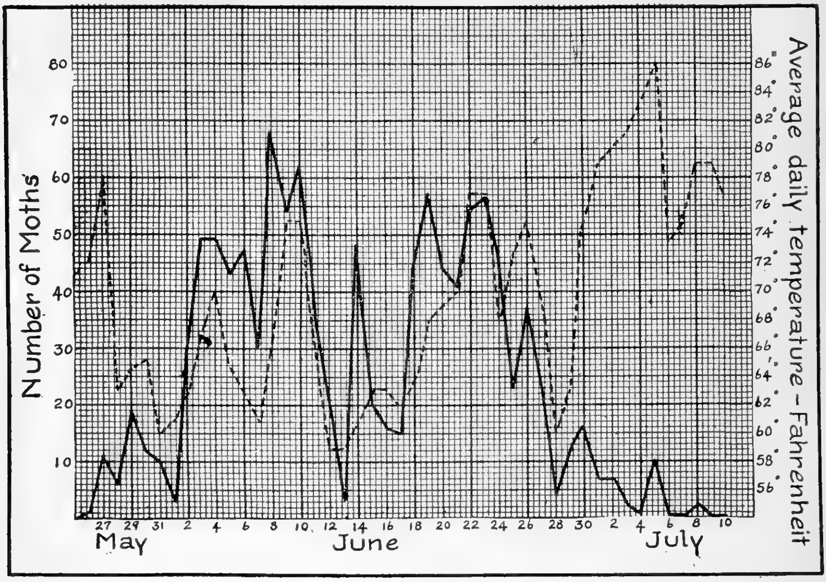


FIG. 14.—Emergence curve of moths of the spring brood in 1911, at Douglas, Mich. (Original.)

been due to the fact that mating had not taken place, it being difficult to find the insects in copulation or to bring about mating by confining together single pairs of male and female moths. In the stock-jar cages, where a number of male and female insects have been confined, eggs have always resulted in abundance and mating must have occurred quite generally though it was only observed on rare occasions. It was therefore planned to remove female moths from the stock jars after the moths had been confined together two or three days, and prior to any egg deposition in the stock jars.

TABLE XXXVII.—*Egg deposition in confinement by individual moths of the spring brood, Douglas, Mich., 1911.*

Date of egg deposition.	Number of individual moths.											
	1	2	3	4	5	6	7	8	9	10	11	12
	Date of emergence of moths.											
	June 4.	June 4.	June 6.	June 11.	June 11.	June 20.	June 20.	June 24.	June 24.	June 26.	June 26.	June 26.
June 10			26									
June 11	1	11										
June 12												
June 13												
June 14												
June 15												
June 16												
June 17				1	33							
June 18	10			8	4							
June 19	2	24		7	37							
June 20	2			20	35							
June 21	20				3							
June 22	8				14							
June 23	14				35							
June 24							6					
June 25	10						26					
June 26	3											
June 27												
June 28									17			
June 29						28		58		2		
June 30						4		28	56	7		
July 1						3			13	40	1	
July 2									15		14	
July 3									1			
July 4												5
July 5												33
	Date of death of moths.											
	July 1.	June 21.	June 10.	(1)	June 25.	July 2.	June 28.	July 8.	July 6.	July 6.	July 6.	July 8.

[1] Escaped June 20.

In all 160 female moths were removed from the different stock jars (Table XL) and were kept isolated in glass tumblers, covered with perforated tin covers. A small piece of sponge dipped in diluted sugar-and-honey solution was inserted to supply food. To encourage egg deposition fresh pear leaves were placed in the tumblers and were daily replaced by fresh foliage at the time the tumblers were examined for eggs.

TABLE XXXVIII.—*Egg deposition by individual moths; summary of Table XXXVII.*

Observations.	Number of individual moths.											
	1	2	3	4	5	6	7	8	9	10	11	12
Total eggs per female	70	35	26	36	161	35	32	86	102	49	15	38
Days before egg deposition	7	7	4	6	6	9	4	5	4	3	5	8
Days duration of egg deposition	16	9	1	4	7	3	2	2	6	3	2	2
Days alive after egg deposition	5	2	0	......	2	1	3	8	3	5	4	3
Days moth lived	27	17	4	......	14	12	8	14	12	10	10	12

TABLE XXXIX.—*Egg deposition by individual moths; summary of Tables XXXVII and XXXVIII.*

Observations.	Average.	Maximum.	Minimum.
Eggs per female	57.08	161	15
Eggs per day per female	16.31	58	1
Days before egg deposition per female	5.66	9	3
Days of egg deposition per female	4.75	16	1
Days moths lived after egg deposition	3.27	8	0
Days moths lived	12.72	27	4

From the 160 separate experiments only 12 yielded results worth recording, and these are given in Tables XXXVII–XXXIX. The following observations are recorded in Table XXXVII: The time of emergence of the different moths, the time and amount of egg deposition per female, and the date of death of each of the female moths. In Table XXXVIII a summary of results will be found showing the number of eggs per female, the number of days before egg deposition, the duration of egg deposition, and the length of life of the moths. It will be noted that on an average these moths commenced to oviposit 5.6 days after their emergence; the maximum length of this period was 9 days and the minimum 3 days. Egg deposition extended on an average over a period of 5 days. The average number of eggs per female was 57.08, the maximum number of eggs per female 161, and the minimum 15 eggs per female. The moths lived, on an average, 3.2 days after egg deposition; in one instance death followed the day after the last oviposition; on the other extreme a single moth lived 8 days after the last egg deposition.

The conditions under which it was necessary to keep these moths for observation were of course quite abnormal and it is doubtful whether all of the moths deposited the normal number of eggs. It is the writer's opinion that in the field the average number of eggs per female is considerably higher and may reach an average of 75 to 85 eggs per female.

Egg deposition in stock-jar experiments.—The nature of the stock-jar tests has already been described on page 13. As will be found in Table XL, the observations merely cover the date of emergence of moths in each cage and the date of the first and last egg depositions per jar, which give only an idea of the extent of the oviposition period. We find from these data that on an average the first eggs were laid four days after the date of emergence of the moths.

TABLE XL.—*Oviposition by moths of the spring brood in rearing cages, Douglas, Mich., 1911.*

Cage No.	Number of moths.	Date of— Emergence of moths.	First oviposition.	Last oviposition.	Number of days— Before oviposition.	Duration of oviposition.	From date of emergence to last oviposition.
1	13	May 24	May 28	June 14	4	18	21
2	20	May 29	June 3	June 21	5	19	23
3	9	May 30	June 10	June 10	11	1	11
4	10	May 31	June 6	June 8	6	3	8
5	5	June 1	...do.....	June 9	5	4	8
6	29	June 2	...do.....	...do.....	4	4	7
7	39	June 3	June 5	June 21	2	17	18
8	47	June 4	June 8	June 20	4	13	16
9	40	June 5	June 9	June 9	4	1	4
10	43	June 6	...do.....	June 24	3	16	18
11	29	June 7	June 10	June 20	3	11	13
12	56	June 8	June 11	June 23	3	13	15
13	45	June 9	June 12	June 15	3	4	6
14	50	June 10	June 13	June 22	3	10	12
15	14	June 17	June 22	June 26	5	5	9
16	48	June 19	June 23	June 27	4	5	8
17	38	June 23	June 25	...do.....	2	3	4
18	44	June 24	June 27	June 30	3	4	6
19	16	June 25	...do.....	July 2	2	6	7
Average					4	8.3	11.3
Maximum					11	19	23
Minimum					2	1	4

The shortest period before first egg deposition was 2 days, and the maximum period 11 days. Within the separate cages oviposition lasted from 1 to 19 days, with an average of 8.3 days. When we consider the period from the date of emergence to the date of last oviposition we find a maximum length of time of 23 days, an average of 11.3 days, and a minimum of 4 days.

Period of egg deposition.—In the field egg deposition is estimated to have taken place from May 28 to July 18, with a maximum number of eggs between June 10 and June 30. This has been estimated from the records of egg deposition by moths in captivity, the time of emergence of the moths, and the band-record observations.

Length of life of moths.—The length of life of 153 male and 177 female moths, confined in the stock jars, is given in Table XLI. On an average the males lived 9.18 days and the females 10.63 days. The maximum length of life for the males was 18 days and for the females 23 days.

TABLE XLI.—*Length of life of male and female moths of the spring brood in captivity; summary of records of 330 individual moths, Douglas, Mich., 1911.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*	
2	2	2	2	14	11	14	9
3	2	3	4	15	8	15	13
4	12	4	6	16	3	16	5
5	11	5	5	17	2	17	5
6	11	6	10	18	1	18	7
7	14	7	13	....	....	19	4
8	18	8	18	....	....	20	2
9	15	9	20	....	....	21	1
10	16	10	22	....	....	23	1
11	11	11	13				
12	15	12	14		153		177
13	1	13	3				

TABLE XLII.—*Length of life of male and emale moths of the spring brood in captivity, Douglas, Mich., 1911; summary of Table XLI.*

Observations.	Life of male moths.	Life of female moths.
	Days.	*Days.*
Average	9.18	10.63
Maximum	18	23
Minimum	2	2

It is of interest to note that in this brood, as well as in the summer brood, the females were more numerous than the males and survived the males on an average by about two days.

THE FIRST GENERATION

FIRST BROOD OF EGGS.

Length of incubation.—Observations on the length of incubation extended over the greatest period when eggs occurred in the field (Table XLIII). The high temperature which at times prevailed brought the minimum length of incubation down to 4 days, against 6 days for the same brood in 1910. The average length of incubation for the brood was 8 days, the maximum 10 days. Observations on the embryological development of the eggs were also taken as recorded in Table XLIII. The so-called "red ring" generally appeared 3 days after egg deposition, and the "black spot" 2 days previous to hatching.

TABLE XLIII.—*Length of incubation of the first brood of eggs and average mean temperature during incubation, Douglas, Mich., 1911.*

No. of observation.	No. of eggs.	Date— Deposited.	Date— Red ring.	Date— Black spot.	Date— Hatched.	Duration of— Red ring.	Duration of— Black spot.	Duration of— Incubation.	Average mean temperature.
						Days.	*Days.*	*Days.*	*F.°*
1	....	May 28	June 1	June 5	June 7	4	8	10	64.27
2	....	May 30	June 3	June 8	June 9	4	9	10	64.21
3	....	June 1	June 4	...do.....	June 10	3	7	9	65.79
4	....	June 4	June 7	June 11	June 12	3	7	8	67.78
5	....	June 3	June 6	June 10	June 11	3	7	8	67.87
6	....	June 5	June 8	....	June 13	3	......	8	66.38
7	....	June 6	....	....	June 15	......	......	9	65.07
8	14	June 8	June 11	June 15	June 17	3	7	9	65.27
9	81	June 9	June 12	June 16	...do.....	3	7	8	65.30
10	15	...do.....	...do.....	...do.....	June 18	3	7	9	64.96
11	146	June 10	June 13	....	June 19	3	......	9	63.68
12	15	...do.....	...do.....	....	June 20	3	......	10	64.12
13	68	June 11	June 14	June 18	...do....	3	7	9	62.93
14	20	...do.....	...do.....	...do.....	June 21	3	7	10	63.58
15	50	June 12	June 15	June 19	...do.....	3	7	9	63.29
16	8	...do.....	...do.....	...do.....	June 22	3	7	10	63.97
17	31	June 13	June 16	June 20	...do.....	3	7	9	64.50
18	46	June 14	June 18	June 21	...do.....	4	7	8	65.21
19	13	...do.....	...do.....	...do.....	June 23	4	7	9	66.55
20	51	June 15	June 19	...do.....	...do.....	4	6	8	67.18
21	18	...do.....	...do.....	...do.....	June 24	4	6	9	68.30
22	60	June 16	June 20	June 22	June 23	4	6	7	67.73
23	18	...do.....	...do.....	...do.....	June 24	4	6	8	68.93
24	....	June 18	June 21	June 23	...do.....	3	5	6	70.95
25	48	June 19	June 22	June 24	June 26	3	5	7	72.10
26	66	June 20	...do.....	...do.....	June 27	2	4	7	73.08
27	17	...do.....	...do.....	June 25	June 28	2	5	8	72.52
28	47	June 21	June 24	June 26	June 27	3	5	6	73.67
29	18	June 22	June 25	June 27	June 28	3	5	6	73.42
30	28	June 24	June 27	June 30	July 1	3	6	7	69.15
31	10	June 26	June 29	July 1	July 2	3	5	6	70.07
32	52	...do.....	...do.....	...do.....	July 3	3	5	7	71.61
33	82	June 27	July 1	July 3	July 4	4	6	7	72.51
34	24	June 28	July 2	...do.....	...do.....	4	5	6	73.16
35	7	June 29	....	July 4	July 5	......	......	6	76.96
36	34	July 2	July 4	July 5	July 6	2	3	4	82.80

TABLE XLIV.—*Incubation periods of first-brood eggs; summary of Table XLIII.*

Appearance of red ring.		Appearance of black spot.		Total incubation period.	
Number of days.	Number of observations.	Number of days.	Number of observations.	Number of days.	Number of observations.
2	3	3	1	4	1
3	21	4	1	6	6
4	10	5	8	7	6
....	....	6	6	8	8
....	....	7	13	9	10
....	....	8	1	10	5
....	....	9	1	....	....

TABLE XLV.—*Incubation periods of first-brood eggs; summary of Tables XLIII and XLIV.*

Observations.	Number of days—		
	For appearance of red ring.	For appearance of black spot.	For incubation.
Average	3.206	6.161	7.944
Maximum	4	9	10
Minimum	2	3	4

TABLE XLVI.—*Average mean temperature during incubation of first brood of eggs, 1911; summary of Table XLIII.*

Number of observations.	Days of incubation.	Average mean temperature.		
		Average.	Maximum.	Minimum.
		° *F.*	° *F.*	° *F.*
1	4	82.80		
6	6	73.04	76.96	70.07
6	7	71.03	73.08	67.73
8	8	67.65	72.52	65.21
10	9	65.03	68.30	62.93
5	10	64.03	64.27	63.58

Effect of temperature upon time of incubation.—One of the greatest factors affecting the time of incubation is the temperature. This is fully shown from the results of the temperature records for the time of incubation both for the first and second broods of eggs as brought out in the curve of figure 15.

Because of the similarity of results obtained, the two broods of eggs are here considered together. The same methods of computing results have been followed as for the spring brood of pupæ (p. 10). In Tables XLIII and LVII the average mean temperature is given for the time of incubation for the different sets of eggs. These data have been summarized into averages under the respective days of the hatching periods. (Tables XLVI and LX.) The curve of figure 15 has been plotted from these combined data, and shows a marked shortening of time under a prevailing high temperature and a prolongation of time under prevailing low temperature.

Taking our readings directly from the curve of figure 15 we get the following average degrees of temperature for the different number of days of incubation:

4 days=83.6° F. or 28.7° C.
5 days=77.0° F. or 25.0° C.
6 days=72.8° F. or 22.8° C.
7 days=70.0° F. or 21.1° C.
8 days=67.5° F. or 19.7° C.
9 days=65.5° F. or 18.6° C.
10 days=64.0° F. or 17.8° C.
11 days=62.7° F. or 17.0° C.
12 days=61.8° F. or 16.6° C.
13 days=61.2° F. or 16.2° C.
14 days=60.6° F. or 16.0° C.
15 days=60.1° F. or 15.6° C.
16 days=59.8° F. or 15.4° C.

The eggs for these experiments were kept in the outdoor rearing shelter, subjected to the normal temperature.

It should be remembered that throughout these tests the temperature has been fluctuating and that the separate obsevations can be only approximately exact and we have therefore obtained a great latitude of variation in degrees of temperature for the respective days. The extent of this variation is shown in Tables XLVI and LX in the maximum and minimum records. Variation in the time of incubation should not entirely be ascribed to inadequate methods of record-

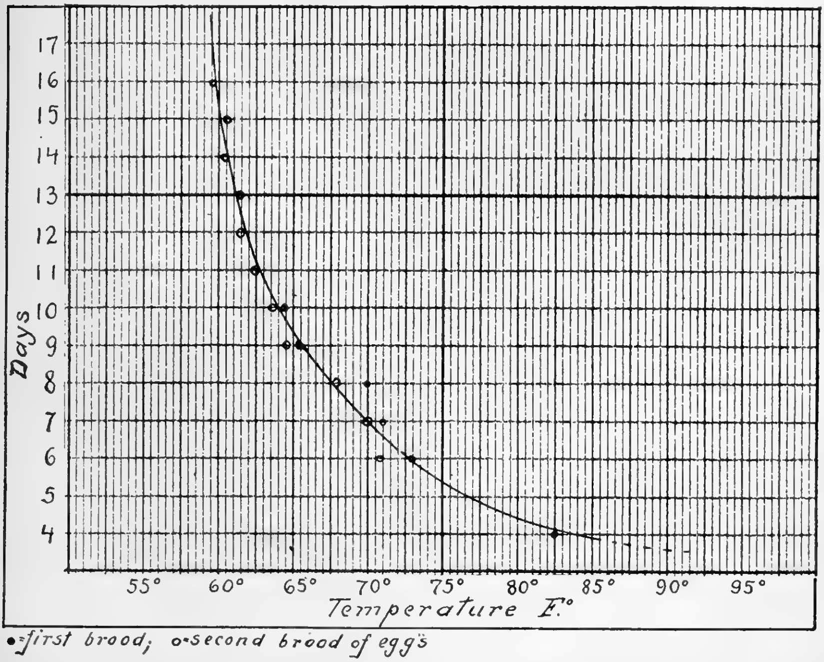


FIG. 15.—Curve showing relation of the temperature to the time of incubation of first-brood and second-brood eggs of the codling moth at Douglas, Mich., 1911. (From Tables XLIII and LVII.) (Original.)

ing observations but also to natural influences other than temperature. It has been constantly found that eggs deposited at the same time have varied several days in hatching. Moisture conditions no doubt also have a bearing upon the length of incubation. The writer has found that eggs do not hatch readily during the prevalence of extremely dry weather.

The "critical" temperature for the eggs of the codling moth can not be determined from the present data. It is therefore not possible to establish the degrees of accumulated effective temperature required for hatching under any given degrees of temperature.

FIRST-BROOD OF LARVÆ.

Time of hatching.—The earliest newly hatched larvæ appeared in the field about June 7, eggs being deposited on May 28 and the first larva from the band records being collected June 27. The greatest number of larvæ hatched between June 17 and July 7. A few isolated larvæ hatched as late as July 20.

Length of feeding period of transforming larvæ.—The feeding period for the transforming larvæ of the first brood was determined from 70 individuals, as given in Table LV. The average length of feeding was 21.25 days, the maximum 29 days, and the minimum 15 days. These results show a shortening of the feeding period as compared with the records for 1910, which must have been due to the exceptionally warm season of 1911.

TABLE XLVII.—*Length of feeding period of wintering larvæ of the first brood, Douglas, Mich., 1911.*

No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving the fruit.	Days feeding.
1	June 7	July 11	34	10	June 22	July 12	20	19	June 26	July 24	28
2	June 13	July 6	23	11	June 23	July 13	20	20	...do.....	July 28	32
3	June 15	July 12	27	12	June 24	July 12	18	21	...do.....	...do.....	32
4	...do.....	July 14	29	13	...do.....	July 15	21	22	...do.....	Aug. 3	38
5	June 18	July 12	24	14	June 26	July 14	18	23	June 27	July 24	27
6	...do.....	July 23	35	15	...do.....	July 18	22	24	...do.....	July 30	33
7	...do.....	...do.....	35	16	...do.....	July 19	23	25	...do.....	...do.....	33
8	June 19	July 19	30	17	...do.....	July 20	24	26	...do.....	Aug. 7	41
9	June 20	July 17	27	18	...do.....	July 23	27	27	...do.....	...do.....	41
Average											28.2
Maximum											41
Minimum											18

Length of feeding period of wintering larvæ.—On comparing records of the feeding period of the wintering larvæ with those of the transforming larvæ it will be noted that there is a marked difference, in that the wintering larvæ fed for a much longer period of time. The average for the wintering larvæ is 28.2 days, the maximum 41 days, and the minimum 18 days (see Table XLVII) and for the transforming larvæ the average is 21.25 days, the maximum 29 days, and the minimum 15 days (Table LV). This difference of habit of the two sets of larvæ was also observed during 1910 and has been referred to in connection with the studies for that year.

About one-half of the first-brood larvæ recorded in Table LV were reared in bagged fruit on the trees, and the other half in fruit in cages.

Within a week of the maturity of the larvæ the bagged fruit was removed from the trees and placed in cages. The average length of feeding of larvæ in bagged fruit was 20.96 days against 21.43 days for those reared in fruit in the cages, being a difference of less than half a day.

Time of maturity of larvæ.—From the band records the time of maturity and the relative abundance of full-grown larvæ are determined for field conditions. The Douglas band records (fig. 18) have been taken as typical and represent also the surrounding sections of the station. The first larvæ were collected June 25 and subsequently in abundance throughout the season. It is estimated that the last larvæ of the first brood appeared September 10.[1]

Percentage of transforming and wintering larvæ.—Table LXVIII shows that 40 per cent of the first-brood larvæ transformed and 60 per cent wintered as larvæ. The observations are from five separate band records.

Larval life in the cocoon.—The larval life in the cocoon is here broadly considered to be the time necessary for the making of the cocoons, and is recorded from the time the larvæ leave the fruit to the time of pupation. More closely considered, this period actually includes the time the larva searches for its hiding place and the prepupal stage, when the larva remains inactive and undergoes structural changes previous to transformation. The wintering larvæ of the first brood are not included here, as these remain in the larval stage until the following spring. The results of 132 observations (Table XLVIII) show a variation of 2 to 18 days and an average of 7.2 days. The data for the extremely short periods of making of cocoons are somewhat misleading in that certain larvæ in the act of making the cocoons have been disturbed by others and have then abandoned the first cocoon and made a new one. The records of Table XLVIII in such instances only show the time for the making of the last cocoon. The prolonged period of time as found in some cases is probably due to a diseased condition of these larvæ.

[1] For methods of determining the time of appearance of the last larvæ of the first brood and the first larvæ of the second brood see page 15.

TABLE XLVIII.—*Length of the pupal stage of the summer brood, Douglas, Mich., 1911.*

No. of observation.	Date of— Leaving fruit.	Date of— Pupation.	Date of— Emergence of moth.	Days— Making of cocoon.	Days— Pupal period.	No. of observation.	Date of— Leaving fruit.	Date of— Pupation.	Date of— Emergence of moth.	Days— Making of cocoon.	Days— Pupal period.
1	July 6	July 9	July 22	3	13	69		July 23	Aug. 5		13
2	do	July 10	July 26	4	16	70	July 14	do	Aug. 6	9	14
3	do	do	July 23	4	15	71		do	Aug. 7		15
4	do	do	do	4	13	72	July 14	Aug. 1	Aug. 14	18	13
5	do	do	July 25	4	15	73	do	do	Aug. 15	18	14
6	do	do	July 23	4	13	74	July 15	July 21	Aug. 5	6	15
7	do	do	July 26	4	16	75	July 16	July 24	Aug. 7	8	14
8	do	do	July 25	4	15	76		do	do		14
9	do	do	July 24	4	14	77	July 17	July 21	Aug. 5	4	15
10	do	do	do	4	14	78	do	do	do	4	15
11	do	do	July 23	4	13	79	do	July 23	Aug. 6	6	14
12	do	do	do	4	13	80	do	do	Aug. 7	6	15
13	do	do	do	4	13	81	do	do	Aug. 8	6	16
14	do	do	July 26	4	16	82	do	July 24	Aug. 3	7	10
15	do	do	do	4	16	83	do	July 25	Aug. 7	8	13
16	do	do	July 28	4	18	84	do	July 26	do	9	12
17	do	do	July 27	4	17	85	do	July 27	Aug. 8	10	12
18	do	July 11	do	5	16	86	do	July 28	Aug. 9	11	12
19	do	do	do	5	16	87	do	do	Aug. 10	11	13
20	do	do	July 26	5	15	88	July 18	July 24	Aug. 7	6	14
21	do	do	Aug. 1	5	21	89	do	do	do	6	14
22	do	do	July 27	5	16	90	do	July 25	Aug. 6	7	12
23	do	do	July 26	5	15	91	do	do	Aug. 7	7	13
24	do	do	do	5	15	92	do	do	do	7	13
25	do	do	July 27	5	16	93	do	do	do	7	13
26	do	do	do	5	16	94	do	July 26	do	8	12
27	do	do	July 28	5	17	95	do	do	do	8	12
28	do	do	July 26	5	15	96	do	do	do	8	12
29	do	July 12	July 28	6	16	97	do	do	do	8	12
30	do	July 14	July 27	8	13	98	do	do	do	8	12
31	do	do	July 30	8	16	99	do	do	do	8	12
32	do	July 17	Aug. 4	11	18	100	do	do	Aug. 8	8	13
33	July 9	July 14	July 30	5	16	101	do	do	do	8	13
34	do	do	July 29	5	15	102	do	do	do	8	13
35	do	do	July 31	5	17	103	do	July 27	Aug. 7	9	11
36	do	do	July 29	5	15	104	do	do	Aug. 8	9	12
37	do	do	July 30	5	16	105	do	do	do	9	12
38	do	do	July 29	5	15	106	do	do	do	9	12
39	do	do	do	5	15	107	do	do	do	9	12
40	do	do	July 30	5	16	108	do	do	do	9	12
41	do	July 15	July 31	6	16	109	do	do	Aug. 10	9	14
42	do	do	do	6	16	110	do	do	Aug. 11	9	15
43	do	do	do	6	16	111	do	July 28	Aug. 7	10	10
44	do	July 17	Aug. 2	8	16	112	do	do	Aug. 9	10	12
45	July 12	do	July 31	5	14	113	do	do	do	10	12
46	do	July 18	Aug. 1	6	14	114	do	do	do	10	12
47	do	do	Aug. 2	6	15	115	do	July 29	Aug. 8	11	10
48	do	do	do	6	15	116	do	do	Aug. 9	11	11
49	do	do	do	6	15	117	do	do	Aug. 10	11	12
50	do	do	Aug. 3	6	16	118	do	do	do	11	12
51	do	do	do	6	16	119	July 19	July 27	Aug. 8	8	12
52	do	do	Aug. 4	6	17	120	do		Aug. 5	13	
53	do	July 19	Aug. 2	7	14	121	July 20	July 29	Aug. 9	9	11
54		do	Aug. 3		15	122	July 21	July 30	do	9	10
55	July 12	do	do	7	15	123	do	Aug. 2	Aug. 14	12	12
56	do	do	do	7	15	124	do	Aug. 6	Aug. 18	16	12
57	do	do	do	7	15	125	July 23	July 31	Aug. 12	8	12
58	do	do	Aug. 4	7	16	126	do	do	do	8	12
59		July 20	Aug. 3		14	127	do	do	Aug. 18	8	18
60	July 12	do	Aug. 4	8	15	128	do	Aug. 8	Aug. 14	16	6
61		do	do		15	129	July 24	Aug. 1	Aug. 15	8	16
62		do	do		15	130	July 25	Aug. 2	Aug. 16	8	14
63	July 12	do	Aug. 5	8	16	131	July 27	Aug. 1	Aug. 14	5	13
64		July 21	Aug. 4		14	132	July 29	Aug. 6	Aug. 22	8	16
65	July 12	do	Aug. 5	9	15						
66		do	do		15	Average				7.2	14.0
67	July 12	July 23	Aug. 5	11	13	Maximum				18	21
68		do	do		13	Minimum				3	6

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—The time of pupation as represented in figure 20 has been determined on the basis that the time and rate of emergence of the moths must be in close relation and in direct proportion to the time and rate of pupation. Observations on pupation in the rearing cages extended from July 6 to August 8. In the field, how-

ever, the pupation period was longer. From the records of emergence of moths we find that the earliest pupæ must have appeared about June 30 and the last pupæ about August 24.

Length of pupal stage.—In the course of rearing work two separate tests on the length of the pupal stage have been made. One of these (Tables XLVIII and XLIX) includes primarily observations on the pupal stage; the other (Table LV) contains observations on the life cycle of the insect. The results of Table XLVIII, including 132 insects, show that the period varied from 6 to 21 days, with an average of 14 days. The results from the life cycle series (Tables LV and LVI), covering 75 observations, showed a variation of 11 to 24 days, and an average of 15.18 days.

TABLE XLIX.—*Length of pupal stage of the summer brood, Douglas, Mich., 1911; summary of Table XLVIII.*

Number of observations.	Days making cocoon.	Number of observations.	Days of pupal period.	Number of observations.	Days making cocoon.	Number of observations.	Days of pupal period.
1	3	13	9	17	14	2	16
18	4	1	6	28	15	2	18
21	5	4	10	5	10	24	16
17	6	3	11	8	11	4	17
10	7	25	12	1	12	3	18
23	8	21	13	1	13	1	21

TABLE L.—*Time of emergence of moths of the summer brood from band records, Douglas, Mich., 1911.*

Date of emergence.	Band records. Douglas.	Lake Shore.	Pentwater.	New Richmond.	Benton Harbor.	Total.	Date of emergence.	Band records. Douglas.	Lake Shore.	Pentwater.	New Richmond.	Benton Harbor.	Total.
July 8	......	......	......	2	3	5	Aug. 13	3	10	6	......	3	22
July 9	......	......	......	......	4	4	Aug. 14	6	13	19	3	12	53
July 10	1	2	4	3	21	33	Aug. 15	1	5	10	......	1	17
July 11	1	2	8	5	16	32	Aug. 16	......	6	8	1	1	16
July 12	......	3	4	......	......	7	Aug. 17	......	8	6	1	3	18
July 13	2	2	16	1	17	38	Aug. 18	1	12	9	......	......	22
July 14	......	2	9	......	19	30	Aug. 19	......	5	3	......	......	8
July 15	......	2	4	......	9	15	Aug. 20	......	......	5	......	......	5
July 16	......	1	2	......	10	13	Aug. 21	3	8	2	4	4	21
July 17	......	1	3	......	11	15	Aug. 22	2	5	5	1	2	15
July 18	......	4	3	1	10	18	Aug. 23	......	3	2	......	1	6
July 19	......	2	5	......	11	18	Aug. 24	2	1	3	......	1	7
July 20	......	2	1	1	8	12	Aug. 25	......	4	2	......	......	6
July 21	......	1	2	......	10	13	Aug. 26	2	3	2	1	......	8
July 22	1	1	1	1	11	15	Aug. 27	......	2	1	1	......	4
July 23	......	6	2	2	8	18	Aug. 28	1	2	2	......	......	5
July 24	......	2	2	1	8	13	Aug. 29	......	2	2	......	......	4
July 25	......	2	2	2	10	16	Aug. 30	......	1	1	......	1	3
July 26	......	9	......	3	9	21	Aug. 31	1	......	1	3	......	5
July 27	......	6	......	2	7	15	Sept. 1	2	1	......	......	......	3
July 28	1	4	2	......	7	14	Sept. 2	1	1	2	1	4	9
July 29	......	4	2	2	11	19	Sept. 3	2	1	......	......	3	6
July 30	2	5	2	1	10	20	Sept. 4	......	2	......	......	1	3
July 31	4	4	4	4	19	35	Sept. 5	......	1	2	1	1	5
Aug. 1	1	2	13	4	19	39	Sept. 6	......	......	1	......	......	1
Aug. 2	......	5	7	......	4	16	Sept. 7	......	1	1	1	......	3
Aug. 3	2	4	15	2	12	35	Sept. 8	......	1	1	......	......	2
Aug. 4	......	4	12	......	13	29	Sept. 9	......	1	......	......	......	1
Aug. 5	10	10	17	2	13	52	Sept. 10	......	......	......	......	1	1
Aug. 6	8	4	12	2	14	40	Sept. 11	......	......	1	......	......	1
Aug. 7	12	15	35	11	17	90	Sept. 16	......	......	......	......	1	1
Aug. 8	4	14	16	7	19	60	Sept. 17	......	......	......	......	1	1
Aug. 9	6	19	20	2	13	60	Sept. 18	......	......	......	......	1	1
Aug. 10	5	22	23	5	12	67							
Aug. 11	1	9	20	3	6	39	Total	91	287	372	89	440	1,279
Aug. 12	3	13	7	......	7	30							

FIRST BROOD OF MOTHS OR SUMMER MOTHS.

Time of emergence.—The records for emergence of summer moths are given in Table L, covering 1,279 observations from five separate band records. The codling-moth larvæ from the band records at Benton Harbor, New Richmond, Douglas, Lake Shore, and Pentwater were all sent to the station at Douglas, and the observations on the date of issue of the moths were all made there. The curve of figure 16 represents the total emergence of moths and is based upon the records of Table L. It will be noted that there existed a striking similarity in the rate of emergence and that the time of emergence

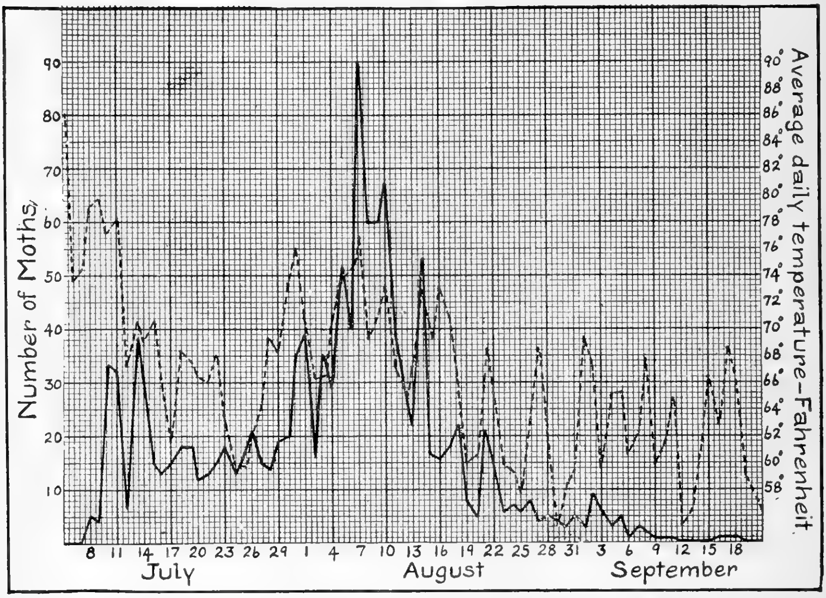


FIG. 16.—Emergence curve of moths of the summer brood in 1911, at Douglas, Mich. (Original.)

was practically the same for the different band records. This may be due to the peculiar climatic conditions of 1911, when the spring opened up uniformly over the entire fruit belt—a rather unusual occurrence. It may also be that during the middle of the summer the seasonal conditions became equalized over the different sections, and produced a corresponding equalizing tendency upon the development of the codling moth.

The emergence records for the summer moths are remarkable both in respect to time and rate of appearance of the moths. The earliest moths issued July 8, which emergence was 21 days earlier then that of the more normal season of 1910. During the early part of the emergence period, from July 10 to July 14, moths appeared in abundance. During the later half of July, however, they were less

numerous, while during the first half of August they were again very abundant, reaching a maximum August 7. During the remaining part of the emergence period, which extended to September 18, comparatively few moths appeared.

TABLE LI.—*Oviposition of moths of the summer brood in captivity, Douglas, Mich., 1911.*

Number of cage.	Number of moths per cage.	Date of— Emergence of moths.	First oviposition.	Last oviposition.	Days— Before oviposition.	Of oviposition.	From time of emergence to last oviposition.
1	29	July 10	July 14	July 20	4	7	10
2	24	July 11	...do.....	July 24	3	11	13
3	10	July 12	...do.....	Aug. 1	2	19	20
4	29	July 13	July 16	July 27	3	12	14
5	26	July 14	July 23	July 24	9	2	10
6	15	July 15	July 18	July 26	3	9	11
7	10	July 16	July 20	July 28	4	9	12
8	14	July 20	July 26	July 31	6	6	11
9	15	July 21	July 28	Aug. 5	7	9	15
10	16	July 22	...do.....	July 30	6	3	8
11	15	July 23	...do.....	Aug. 4	5	8	12
12	13	July 25	July 27	...do.....	2	9	10
13	25	July 26	July 31	Aug. 1	5	2	6
14	11	July 27	...do.....	Aug. 2	4	3	6
15	14	July 28	Aug. 1	Aug. 7	4	7	10
16	17	July 29	July 31	Aug. 14	2	15	16
17	18	July 30	Aug. 1	Aug. 10	2	10	11
18	36	July 31	Aug. 2	Aug. 18	2	17	18
19	37	Aug. 1	Aug. 6	Aug. 7	5	2	6
20	15	Aug. 2	Aug. 5	Aug. 9	3	5	7
21	38	Aug. 3	Aug. 6	Aug. 15	3	10	12
22	34	Aug. 4	...do.....	Aug. 16	2	11	12
23	54	Aug. 5	Aug. 7	Aug. 12	2	6	7
24	35	Aug. 6	Aug. 8	Aug. 13	2	6	7
25	88	Aug. 7	Aug. 9	Aug. 16	2	8	9
26	55	Aug. 9	Aug. 11	Aug. 17	2	7	8
27	54	Aug. 10	Aug. 12	Aug. 31	2	20	21
28	27	Aug. 12	Aug. 13	Aug. 23	1	11	11
29	19	Aug. 13	Aug. 17	Aug. 21	4	5	8
30	47	Aug. 14	Aug. 16	Aug. 25	2	10	11
31	21	Aug. 16	Aug. 18	Aug. 28	2	11	12
32	16	Aug. 17	...do.....	Sept. 3	1	17	17
33	27	Aug. 18	Aug. 21	Aug. 28	3	8	10
34	23	Aug. 21	Aug. 22	Sept. 14	1	24	24
35	15	Aug. 22	Aug. 25	Sept. 3	3	10	12
Average					3.2	9.4	11.6
Maximum					9	24	24
Minimum					1	2	6

Time of oviposition.—Observations on egg deposition by the summer moths in captivity were made under conditions already described on page 14 for the spring brood. The results as presented in Table LI show that on an average the first eggs were laid 3 days after the time of emergence of the moths and that oviposition extended on an average to 9.4 days. Within the various cages considerable variation will be noted; in one instance the first eggs were obtained the following day after the emergence, in another instance the ninth day; in one cage the last eggs were deposited the sixth day, and in another cage the twenty-fourth day after the time of emergence of the moths.

On correlating the above observations with the time of emergence of the moths it will be found that the oviposition period extended from about July 11 to September 25. However, very few eggs were laid during September, and not all of these hatched. The great majority of eggs were deposited during August.

TABLE LII.—*Length of life of male and female moths of the first brood; summary of records of 1,019 individual moths.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*	
1	1	1	1	18	6	18	10
2	8	2	5	19	2	19	9
3	16	3	6	20	5	20	10
4	22	4	15	21	2	21	13
5	22	5	24	22	1	22	9
6	42	6	32	23	2	23	2
7	46	7	27	25	1	24	2
8	48	8	62	26	1	26	4
9	50	9	46	32	1	28	1
10	41	10	53			29	2
11	30	11	48			30	1
12	32	12	43			32	1
13	18	13	40			33	1
14	24	14	33			37	1
15	12	15	26				
16	11	16	22	Total..	456		563
17	12	17	14				

TABLE LIII.—*Longevity of male and female moths of the first brood; summary of Table LII.*

Observations.	Life of male moths.	Life of female moths.
	Days.	*Days.*
Average	9.57	11.49
Maximum	32	37
Minimum	1	1

Length of life of male and female moths.—A summary of observations from 1,910 individual moths is recorded in Table LII. The condition under which the moths were kept has already been referred to on page 39. As observed for the previous brood, the longevity of the males was shorter than that for the females. On an average the males lived 9.57 days and the females 11.49 days; the maximum length of life for the males was 32 days and for the females 37 days.

It is of interest to note that the results obtained by the writer at North East, Pa., in 1909,[1] are almost identical with those given above; the average length of life for the males being 9.79 days and for the females 11.47 days.

[1] Bul. 80, Pt. VI, Bur. Ent., U. S. Dept. Agr., p. 91, 1910.

The females were found to be more numerous than the males, which was also observed in the spring brood of moths.

Length of life cycle of the first generation.—In Table LIV are brought together the average results from observations for the separate stages of the first generation. These data show that on an average there elapsed 53.59 days from the time of appearance of eggs of the first brood to the time of appearance of eggs of the second brood. Comparing these results with those of the complete life-cycle series (Tables LV–LVI), there will be found a difference of results of less than one day. In the life-cycle tests 75 individual insects were under observation from the time of the deposition of the eggs to the time of emergence of the moths that resulted from these eggs.

TABLE LIV.—*Summary of results from experiments on the separate stages of the first generation of the codling moth in 1911.*

Life cycle of first generation.	Number of days.		
	Average.	Maximum.	Minimum.
Incubation of eggs	7.94	10	4
Feeding period of larvæ	21.25	29	15
Making of cocoons	7.2	18	3
Pupal stages	14.0	21	6
Time before egg deposition	3.2	9	1
Total	53.59	87	29

TABLE LV.—*Life cycle of the first generation of the codling moth, as observed by rearing at Douglas, Mich., in 1911.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Total life cycle.
1	June 1	June 10	July 4	July 9	July 22	9	24	5	13	51
2	...do.....	...do.....	...do.....	July 11	....	9	24	7	....	....
3	...do.....	...do.....	...do.....	...do.....	July 27	9	24	7	16	56
4	June 3	June 11	...do.....	July 8	....	8	23	4	....	....
5	June 5	June 13	July 8	July 26	Aug. 8	8	25	18	13	64
6	...do.....	...do.....	July 9	July 14	July 31	8	26	5	17	56
[1] 7	June 6	June 15	July 6	July 9	July 23	9	21	3	14	47
[1] 8	...do.....	...do.....	July 8	July 11	July 26	9	23	3	15	50
[1] 9	...do.....	...do.....	...do.....	...do.....	...do.....	9	23	3	15	50
[1] 10	...do.....	...do.....	...do.....	...do.....	...do.....	9	23	3	15	50
[1] 11	...do.....	...do.....	...do.....	July 18	Aug. 3	9	23	10	16	58
[1] 12	...do.....	...do.....	July 9	July 16	Aug. 1	9	24	7	16	56
[1] 13	...do.....	...do.....	....	....	[2] July 31	9	....	....	....	55
[1] 14	...do.....	...do.....	....	....	[2] July 25	9	....	....	....	49
[1] 15	June 8	June 18	July 8	July 11	....	10	20	3	....	....
[1] 16	...do.....	...do.....	July 12	July 24	Aug. 7	10	24	12	14	60
[1] 17	June 9	...do.....	July 8	July 12	July 31	9	20	4	19	52
[1] 18	...do.....	...do.....	July 9	July 13	July 30	9	21	4	17	51
[1] 19	...do.....	...do.....	...do.....	July 18	Aug. 3	9	21	9	16	55
[1] 20	...do.....	...do.....	July 12	July 14	July 31	9	24	2	17	52
21	June 10	June 19	July 8	July 13	July 29	9	19	5	16	49
22	...do.....	...do.....	July 13	July 23	....	9	24	10	....	....
23	...do.....	...do.....	July 14	...do.....	....	9	25	9	....	....
24	...do.....	...do.....	...do.....	July 21	Aug. 5	9	25	7	15	56
25	...do.....	...do.....	July 15	July 22	....	9	26	7	....	....
26	June 11	June 20	July 6	July 10	July 23	9	16	4	13	42

[1] Bagged fruit; average feeding, 20.9 days.

[2] Pupated in fruit; average feeding, 21.4 days.

TABLE LV.—*Life cycle of the first generation of the codling moth, as observed by rearing at Douglas, Mich., in 1911*—Continued.

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Total life cycle.
27	June 11	June 20	July 7	July 12	....	9	17	5	....	....
28	...do.....	...do.....	...do.....	...do.....	July 29	9	17	5	17	48
29	...do.....	...do.....	July 9	July 13	July 30	9	19	4	17	49
30	...do.....	...do.....	July 13	July 18	Aug. 4	9	23	5	17	54
31	...do.....	...do.....	...do.....	July 20	Aug. 5	9	23	7	16	55
[1] 32	...do.....	...do.....	July 7	July 12	July 28	9	17	5	16	47
[1] 33	...do.....	...do.....	July 9	July 13	July 31	9	19	4	18	50
[1] 34	...do.....	...do.....	...do.....	July 12	July 28	9	19	3	16	47
[1] 35	...do.....	...do.....	July 13	July 19	Aug. 4	9	23	6	16	54
36	June 12	June 21	July 6	July 9	July 22	9	15	3	13	40
37	...do.....	...do.....	July 8	July 14	July 31	9	17	6	17	49
38	...do.....	...do.....	July 10	July 16	Aug. 1	9	19	6	16	50
39	...do.....	...do.....	...do.....	July 15	July 31	9	19	5	16	49
40	...do.....	...do.....	...do.....	July 16	Aug. 2	9	19	6	17	51
41	...do.....	...do.....	July 11	...do.....	Aug. 9	9	20	5	24	58
42	...do.....	...do.....	...do.....	July 15	July 31	9	20	4	16	49
[1] 43	...do.....	...do.....	July 9	...do.....	...do.....	9	18	6	16	49
[1] 44	...do.....	...do.....	July 15	....	Aug. 8	9	24	....	....	57
[1] 45	...do.....	...do.....	....	....	[2] July 31	9	....	....	....	49
46	June 13	June 22	July 11	July 20	Aug. 4	9	19	9	15	52
47	...do.....	...do.....	...do.....	July 18	...do.....	9	19	7	17	52
48	...do.....	...do.....	July 12	...do.....	Aug. 3	9	20	6	16	51
49	...do.....	...do.....	...do.....	July 21	Aug. 5	9	20	9	15	53
[1] 50	June 14	...do.....	July 10	July 15	July 31	8	18	5	16	47
[1] 51	...do.....	...do.....	July 11	July 16	Aug. 1	8	19	5	16	48
[1] 52	...do.....	...do.....	...do.....	July 17	...do.....	8	19	6	15	48
[1] 53	...do.....	...do.....	July 21	July 29	Aug. 10	8	29	8	12	57
[1] 54	...do.....	...do.....	....	....	[2] Aug. 1	8	....	....	....	48
55	June 15	June 23	July 9	July 14	July 30	8	16	5	16	45
56	...do.....	...do.....	July 12	July 18	....	8	19	6	....	....
57	...do.....	...do.....	July 18	July 26	Aug. 8	8	25	8	13	54
[1] 58	June 16	...do.....	July 12	July 17	Aug. 2	7	19	5	16	47
[1] 59	...do.....	...do.....	...do.....	July 19	Aug. 4	7	19	7	16	49
[1] 60	...do.....	...do.....	July 13	July 18	Aug. 1	7	20	5	14	46
61	June 18	June 24	July 12	July 27	....	6	18	15	....	....
62	...do.....	...do.....	July 17	July 30	Aug. 10	6	23	13	11	53
63	...do.....	...do.....	July 18	...do.....	....	6	24	12	....	....
64	...do.....	...do.....	July 20	July 28	Aug. 9	6	26	8	12	52
65	...do.....	...do.....	July 23	July 29	Aug. 10	6	29	6	12	53
66	June 19	June 26	July 15	July 26	Aug. 9	7	19	11	14	51
67	June 20	June 27	July 12	July 20	Aug. 5	7	15	8	16	46
68	...do.....	...do.....	July 24	July 29	Aug. 10	7	27	5	12	51
69	...do.....	...do.....	....	Aug. 4	Aug. 18	7	....	....	14	59
[1] 70	...do.....	...do.....	July 14	July 21	Aug. 5	7	17	7	15	46
[1] 71	...do.....	...do.....	...do.....	July 23	Aug. 6	7	17	9	14	47
[1] 72	...do.....	...do.....	July 20	July 29	Aug. 10	7	23	9	12	51
73	June 26	July 3	July 28	Aug. 3	Aug. 15	7	25	6	12	50
74	June 27	July 4	...do.....	...do.....	...do.....	7	24	6	12	49
75	...do.....	...do.....	...do.....	Aug. 6	Aug. 19	7	24	9	13	53

[1] Bagged fruit; average feeding, 20.9 days. [2] Pupated in fruit; average feeding, 21.4 days.

TABLE LVI.—*Length of the life cycle of the first generation; summary of Table LV.*

Observations.	Days for—				
	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Total life cycle.
Average....................	8.33	21.25	6.54	15.18	51.10
Maximum....................	10	29	18	24	64
Minimum....................	6	15	2	11	42

It is of interest to note the extent of variation in the length of the life cycle of the first generation. The figures of Table LIV show a maximum length of time for the entire life cycle of 87 days and a minimum of 29 days, or a range of variation of 58 days. From the above results it becomes evident that reliable conclusions can not be made from a limited number of observations no matter how accurate the records may be; they only represent the results under limited conditions. Such conclusions may readily become extremely misleading when used as a basis for timing spray applications. By using the average length of the life cycle of 51 days it will be found that three broods of the codling moth could have existed in the Michigan fruit belt in 1911. Or should we, on the other hand, choose to use the records for the minimum length of the life cycle we could on that basis account for the existence of a fourth brood of the codling moth. Our observations, however, only show evidence of two broods, since out of several thousand larvæ of the second brood not a single insect pupated in 1911.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Time of incubation.—Eggs of the second brood occurred in the field for about three months. During this long period the different eggs were often subjected to strikingly different climatic conditions, which resulted in an unusual degree of variation in the time of incubation. In Table LVII are included the records for 110 observations. The time of incubation here varied from 6 to 16 days and averaged 9.35 days for the whole period. During the latter part of July and first half of August, when the greatest abundance of eggs was found, the time of incubation varied from 6 to 8 days. As for the first brood of eggs, observations were also made on the embryological development of the second brood of eggs, namely, the time of appearance of the "red ring" and the "black spot." The summarized results in Table LIX show that the red ring appeared on an average within 3 days after egg deposition and the black spot 2 days previous to hatching. A number of eggs deposited during the middle part of September failed to hatch, mostly due to the prevailing low temperature. The fact that the red ring had already appeared in these eggs proved them to be fertile.

All of the eggs used in these tests were laid in the rearing cages, and there were 4,643 eggs under observation as listed in Table LVII.

TABLE LVII.—*Length of incubation of the second brood of eggs, and average temperature during incubation, Douglas, Mich., 1911.*

No. of observation.	Number of eggs.	Date of— Egg deposition.	Appearance of red ring.	Appearance of black spot.	Hatching.	Duration of— Red ring.	Black spot.	Incubation.	Average mean temperature.
						Days.	*Days.*	*Days.*	°*F.*
1	18	July 14	July 18	July 20	July 22	4	6	8	66.96
2	23	July 15	July 19	July 21	July 23	4	6	8	66.83
3	35	July 17	July 21	July 23	July 24	4	6	7	66.00
4	59	July 18	July 23	July 25	July 28	5	7	10	64.60
5	67	July 19	July 24	July 27	...do....	5	8	9	64.18
6	15	...do....	...do....	...do....	July 29	5	8	10	64.67
7	64	July 20	July 26	July 28	...do....	6	8	9	64.35
8	8	...do....	...do....	...do....	July 30	6	8	10	64.73
9	5	July 22	July 27	July 29	July 31	5	7	9	65.41
10	8	...do....	...do....	...do....	Aug. 1	5	7	10	66.47
11	27	July 23	July 28	July 30	July 31	5	7	8	65.09
12	25	...do....	...do....	July 31	Aug. 1	5	8	9	66.30
13	15	July 24	July 29	...do....	...do....	5	7	8	66.63
14	17	July 26	July 31	Aug. 1	Aug. 2	5	6	7	69.20
15	12	July 27	...do....	...do....	...do....	4	5	6	70.33
16	4	...do....	...do....	...do....	Aug. 3	4	5	7	69.76
17	12	July 28	July 30	Aug. 2	...do....	2	5	6	70.70
18	4	...do....	...do....	...do....	Aug. 4	2	5	7	70.08
19	14	July 29	Aug. 2	Aug. 3	...do....	4	5	6	70.23
20	3	...do....	...do....	...do....	Aug. 5	4	5	7	70.22
21	172	July 30	...do....	Aug. 4	...do....	3	5	6	70.55
22	12	...do....	...do....	...do....	Aug. 6	3	5	7	71.00
23	95	July 31	...do....	Aug. 5	...do....	2	5	6	70.54
24	30	...do....	...do....	...do....	Aug. 7	2	5	7	71.07
25	46	Aug. 1	Aug. 3	...do....	...do....	2	4	6	70.25
26	22	...do....	...do....	Aug. 6	Aug. 8	2	5	7	71.22
27	72	Aug. 2	Aug. 4	Aug. 7	...do....	2	5	6	71.29
28	4	...do....	...do....	...do....	Aug. 9	2	5	7	71.01
29	40	Aug. 3	Aug. 5	Aug. 8	...do....	2	5	6	71.81
30	8	...do....	Aug. 6	...do....	Aug. 10	3	5	7	71.74
31	30	Aug. 4	...do....	Aug. 9	Aug. 11	2	5	7	72.61
32	111	Aug. 5	Aug. 8	Aug. 10	...do....	3	5	6	73.01
33	17	...do....	Aug. 7	...do....	Aug. 12	2	5	7	72.20
34	146	Aug. 6	Aug. 8	Aug. 11	...do....	2	5	6	71.95
35	60	...do....	...do....	...do....	Aug. 13	2	5	7	71.00
36	188	Aug. 7	...do....	Aug. 12	Aug. 14	1	5	7	69.97
37	18	...do....	...do....	Aug. 13	Aug. 15	1	6	8	70.39
38	309	Aug. 8	Aug. 11	Aug. 14	...do....	3	6	7	66.59
39	3	...do....	...do....	...do....	Aug. 16	3	6	8	69.47
40	3	Aug. 9	Aug. 12	...do....	Aug. 15	3	5	6	69.47
41	99	...do....	...do....	...do....	Aug. 16	3	5	7	69.49
42	13	...do....	...do....	Aug. 15	Aug. 17	3	6	8	69.96
43	298	Aug. 10	Aug. 13	...do....	...do....	3	5	7	69.86
44	4	...do....	...do....	...do....	Aug. 18	3	5	8	69.99
45	310	Aug. 11	...do....	Aug. 16	Aug. 17	2	5	6	69.33
46	130	...do....	Aug. 14	...do....	Aug. 18	3	5	7	69.56
47	37	...do....	...do....	Aug. 17	Aug. 19	3	6	8	69.15
48	128	Aug. 12	Aug. 15	...do....	Aug. 18	3	5	6	69.92
49	37	...do....	...do....	...do....	Aug. 19	3	5	7	69.40
50	130	Aug. 13	Aug. 16	Aug. 18	Aug. 20	3	6	7	68.65
51	102	...do....	...do....	...do....	Aug. 21	3	6	8	67.68
52	87	Aug. 14	Aug. 17	Aug. 19	...do....	3	5	7	67.77
53	58	...do....	...do....	Aug. 20	Aug. 22	3	6	8	67.86
54	198	Aug. 15	...do....	Aug. 21	...do....	2	6	7	67.07
55	68	...do....	...do....	...do....	Aug. 23	2	6	8	66.85
56	8	...do....	...do....	...do....	Aug. 24	2	6	9	66.08
57	8	...do....	...do....	Aug. 22	Aug. 25	2	7	10	65.40
58	37	Aug. 16	Aug. 19	Aug. 23	Aug. 24	3	7	8	65.63
59	17	...do....	...do....	...do....	Aug. 25	3	7	9	66.04
60	27	...do....	Aug. 20	Aug. 24	Aug. 26	4	8	10	64.23
61	8	...do....	...do....	...do....	Aug. 27	4	8	11	64.16
62	21	Aug. 17	Aug. 19	...do....	Aug. 26	2	7	9	63.22
63	39	...do....	Aug. 20	Aug. 25	Aug. 27	3	8	10	63.24
64	40	...do....	...do....	...do....	Aug. 28	3	8	11	63.72
65	206	Aug. 18	...do....	Aug. 26	...do....	2	8	10	62.99
66	18	...do....	...do....	Aug. 27	Aug. 29	2	9	11	62.97
67	26	Aug. 19	Aug. 21	Aug. 28	Aug. 30	2	9	11	62.00
68	4	...do....	...do....	...do....	Aug. 31	2	9	12	61.69
69	119	Aug. 21	Aug. 23	Aug. 30	Sept. 1	2	9	11	61.71
70	28	...do....	...do....	...do....	Sept. 2	2	9	12	62.36
71	32	Aug. 22	Aug. 25	...do....	Sept. 1	3	8	10	61.03

TABLE LVII.—*Length of incubation of the second brood of eggs, and average temperature during incubation, Douglas, Mich., 1911*—Continued.

No. of observation.	Number of eggs.	Date of— Egg deposition.	Appearance of red ring.	Appearance of black spot.	Hatching.	Duration of— Red ring.	Black spot.	Incubation.	Average mean temperature.
						Days.	*Days.*	*Days.*	°*F.*
72	80	Aug. 22	Aug. 25	Aug. 30	Sept. 2	3	8	11	61.81
73	50	Aug. 24	Aug. 26	Sept. 2	Sept. 4	2	9	11	61.96
74	3	...do....	...do....	...do....	Sept. 5	2	9	12	62.23
75	21	Aug. 26	Aug. 30	...do....	...do....	4	7	10	62.95
76	46	Aug. 27	Aug. 31	Sept. 3	...do....	4	7	9	62.90
77	16	...do....	...do....	...do....	Sept. 6	4	7	10	63.17
78	26	Aug. 28	...do....	Sept. 5	...do....	3	8	9	62.59
79	8	...do....	...do....	...do....	Sept. 7	3	8	10	62.41
80	12	...do....	Sept. 1	Sept. 6	Sept. 8	4	9	11	62.39
81	3	...do....	...do....	...do....	Sept. 9	4	9	12	62.84
82	8	Aug. 30	Sept. 2	Sept. 8	...do....	3	9	10	63.58
83	5	...do....	...do....	...do....	Sept. 10	3	9	11	63.27
84	6	Aug. 31	Sept. 3	Sept. 9	...do....	3	9	10	63.77
85	9	...do....	...do....	...do....	Sept. 11	3	9	11	63.60
86	10	Sept. 2	Sept. 6	Sept. 12	Sept. 15	4	10	13	62.14
87	40	Sept. 8	Sept. 11	Sept. 16	Sept. 18	3	8	10	62.46
88	20	...do....	...do....	...do....	Sept. 19	3	8	11	62.85
89	5	Sept. 9	Sept. 12	Sept. 17	...do....	3	8	10	62.34
90	3	...do....	...do....	Sept. 18	Sept. 20	3	9	11	62.06
91	1	...do....	...do....	...do....	Sept. 25	3	9	16	61.09
92	1	Sept. 10	Sept. 13	Sept. 19	Sept. 21	3	9	11	61.86
93	2	...do....	...do....	...do....	Sept. 22	3	9	12	61.39
94	1	...do....	...do....	Sept. 20	Sept. 24	3	10	14	61.09
95	29	Sept. 11	Sept. 15	...do....	Sept. 22	4	9	11	61.35
96	16	...do....	...do....	...do....	Sept. 23	4	9	12	60.92
97	1	...do....	Sept. 16	Sept. 21	Sept. 24	5	10	13	61.03
98	1	...do....	...do....	Sept. 22	Sept. 25	5	11	14	61.11
99	3	Sept. 12	...do....	...do....	Sept. 24	4	10	12	60.71
100	1	...do....	...do....	...do....	Sept. 25	4	10	13	60.81
101	19	Sept. 13	Sept. 17	...do....	Sept. 24	4	9	11	61.19
102	6	...do....	...do....	...do....	Sept. 25	4	9	12	61.27
103	4	...do....	...do....	Sept. 23	Sept. 26	4	10	13	60.93
104	1	...do....	...do....	...do....	Sept. 27	4	10	14	60.43
105	1	...do....	...do....	...do....	Sept. 28	4	10	15	60.47
106	5	Sept. 14	...do....	Sept. 22	Sept. 24	3	8	10	61.68
107	1	...do....	...do....	Sept. 23	Sept. 28	3	9	14	60.76
108	7	Sept. 17	Sept. 25	Sept. 27	Sept. 29	8	10	12	59.60
109	1	...do....	...do....	...do....	Oct. 1	8	10	14	58.55
110	2	...do....	...do....	...do....	Oct. 3	8	10	16	57.80

TABLE LVIII.—*Length of incubation of second-brood eggs laid in rearing cages, Douglas, Mich., 1911; summary of Table LVII.*

Appearance of red ring.		Appearance of black spot.		Total incubation period.	
Number of days.	Number of observations.	Number of days.	Number of observations.	Number of days.	Number of observations.
1	2	4	1	6	13
2	27	5	30	7	22
3	41	6	15	8	13
4	24	7	12	9	9
5	11	8	18	10	17
6	2	9	22	11	15
8	3	10	11	12	9
....	....	11	1	13	4
....	....	....	....	14	5
....	....	....	....	15	1
....	....	....	....	16	2

TABLE LIX.—*Length of incubation of second-brood eggs laid in rearing cages, Douglas, Mich., 1911; summary of Tables LVII and LVIII.*

Observations.	Number of days—		
	For appearance of red ring.	For appearance of black spot.	For incubation.
Average	3.33	7.19	9.35
Maximum	8	11	16
Minimum	1	4	6

Effect of temperature upon the time of incubation.—The general effect of the temperature upon the time of incubation of the codling moth eggs has already been considered on page 44 and the results for the second brood of eggs have there been given in the diagram (fig. 15) together with those for the first brood. In Table LVII the average daily temperature is given for the 110 separate observations. These temperature records have further been summarized to averages for the respective days of incubation as given in Table LX. The range in variation of average degrees of temperature for the different days is shown in the same table in the columns of maximum and minimum.

TABLE LX.—*Average mean temperature during incubation of second-brood eggs, Douglas, Mich., 1911; summary of Table LVII.*

Days of incubation.	Number of observations.	Average mean temperature.		
		Average.	Maximum.	Minimum.
		° *F.*	° *F.*	° *F.*
6	13	70.72	73.01	69.33
7	22	69.79	72.61	66.00
8	13	67.88	70.39	65.09
9	9	64.56	66.30	62.59
10	17	63.51	66.47	61.03
11	15	62.46	64.16	61.19
12	9	61.45	62.84	59.60
13	4	61.23	62.14	60.81
14	5	60.39	61.11	58.55
15	1	60.47		
16	2	59.44	61.09	57.80

SECOND BROOD OF LARVÆ.

Time of hatching.—In the field the hatching period extended from July 18 to October 3. The great majority of larvæ hatched during the latter part of July and throughout August; during September only a few appeared. The period of hatching of larvæ of the second brood, extending over two months and a half, is very exceptional in comparison with the records for a normal season. During 1910 the period of hatching of eggs of the second brood was less than one month and a half.

TABLE LXI.—*Length of feeding period of second-brood larvæ, Douglas, Mich., 1911.*

No. of observation.	Date of— Hatching.	Date of— Leaving fruit.	Days of feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving fruit.	Days of feeding.	No. of observation.	Date of— Hatching.	Date of— Leaving fruit.	Days of feeding.
1	July 23	Aug. 18	26	69	Aug. 12	Oct. 10	59	137	Aug. 20	Oct. 7	48
2	...do.....	Aug. 19	27	70	...do.....	Oct. 12	61	138	...do.....	...do.....	48
3	July 24	...do.....	26	71	...do.....	Oct. 20	69	139	...do.....	...do.....	48
4	...do.....	Aug. 21	28	72	Aug. 15	Sept. 4	20	140	...do.....	Oct. 8	49
5	...do.....	Aug. 28	35	73	...do.....	Sept. 6	22	141	...do.....	Oct. 11	52
6	...do.....	...do.....	35	74	...do.....	Sept. 17	33	142	...do.....	Oct. 13	54
7	...do.....	Sept. 5	43	75	...do.....	...do.....	33	143	Aug. 21	Sept. 21	31
8	July 28	Aug. 19	22	76	...do.....	Sept. 18	34	144	...do.....	Sept. 26	36
9	...do.....	...do.....	22	77	...do.....	Sept. 19	35	145	...do.....	...do.....	36
10	...do.....	Aug. 20	23	78	...do.....	Sept. 26	42	146	...do.....	Oct. 1	41
11	...do.....	Aug. 21	24	79	...do.....	Sept. 28	44	147	...do.....	Oct. 3	43
12	...do.....	...do.....	24	80	...do.....	...do.....	44	148	...do.....	Oct. 6	46
13	...do.....	...do.....	24	81	...do.....	Sept. 29	45	149	...do.....	Nov. 13	84
14	...do.....	Aug. 22	25	82	Aug. 16	Sept. 12	27	150	Aug. 22	Sept. 29	38
15	...do.....	Aug. 26	29	83	...do.....	Sept. 14	29	151	...do.....	...do.....	38
16	...do.....	Aug. 27	30	84	...do.....	...do.....	29	152	...do.....	...do.....	38
17	...do.....	Aug. 28	31	85	...do.....	Sept. 17	32	153	...do.....	Oct. 7	46
18	...do.....	...do.....	31	86	...do.....	...do.....	32	154	...do.....	Oct. 8	47
19	...do.....	Aug. 29	32	87	...do.....	...do.....	32	155	...do.....	Oct. 14	53
20	...do.....	Sept. 1	35	88	...do.....	Sept. 24	39	156	...do.....	Oct. 16	55
21	...do.....	Sept. 2	36	89	...do.....	Sept. 25	41	157	Aug. 23	Oct. 1	39
22	...do.....	...do.....	36	90	...do.....	Oct. 26	71	158	...do.....	Oct. 3	41
23	...do.....	Sept. 4	38	91	Aug. 17	Sept. 8	22	159	...do.....	Oct. 6	44
24	July 29	Aug. 21	23	92	...do.....	Sept. 15	29	160	...do.....	...do.....	44
25	...do.....	...do.....	23	93	...do.....	Sept. 17	31	161	...do.....	Oct. 16	54
26	...do.....	...do.....	23	94	...do.....	...do.....	31	162	Aug. 24	Sept. 29	36
27	...do.....	...do.....	23	95	...do.....	Sept. 19	33	163	...do.....	...do.....	36
28	...do.....	Aug. 24	26	96	...do.....	Sept. 22	36	164	...do.....	Oct. 3	40
29	...do.....	...do.....	26	97	...do.....	...do.....	36	165	...do.....	...do.....	40
30	...do.....	Aug. 29	31	98	...do.....	...do.....	36	166	Aug. 25	Sept. 28	34
31	July 31	Aug. 28	28	99	...do.....	...do.....	36	167	...do.....	...do.....	34
32	...do.....	...do.....	28	100	...do.....	Sept. 23	37	168	...do.....	Oct. 7	43
33	...do.....	Aug. 31	31	101	...do.....	...do.....	37	169	...do.....	Oct. 20	56
34	...do.....	Sept. 7	38	102	...do.....	...do.....	37	170	Aug. 26	Sept. 28	33
35	Aug. 4	Aug. 28	24	103	...do.....	Sept. 24	38	171	...do.....	Oct. 6	41
36	...do.....	Aug. 29	25	104	...do.....	...do.....	38	172	...do.....	Oct. 15	50
37	...do.....	Sept. 7	34	105	...do.....	Sept. 26	40	173	...do.....	Oct. 16	51
38	...do.....	Sept. 9	36	106	...do.....	...do.....	40	174	...do.....	...do.....	51
39	Aug. 6	Sept. 4	29	107	...do.....	...do.....	40	175	...do.....	Oct. 17	52
40	...do.....	...do.....	29	108	...do.....	...do.....	40	176	...do.....	Oct. 20	55
41	...do.....	...do.....	29	109	...do.....	...do.....	40	177	...do.....	Oct. 23	58
42	...do.....	Sept. 11	36	110	...do.....	Sept. 29	43	178	Aug. 27	Oct. 8	42
43	...do.....	Sept. 16	41	111	...do.....	...do.....	43	179	...do.....	Oct. 9	43
44	...do.....	Sept. 26	51	112	...do.....	...do.....	43	180	...do.....	Oct. 15	49
45	Aug. 7	Aug. 28	21	113	...do.....	Oct. 1	45	181	...do.....	Oct. 16	50
46	...do.....	Sept. 4	28	114	...do.....	...do.....	45	182	Aug. 28	Oct. 14	47
47	Aug. 11	...do.....	24	115	...do.....	...do.....	45	183	...do.....	Oct. 17	50
48	...do.....	Sept. 11	31	116	...do.....	...do.....	45	184	...do.....	Oct. 20	53
40	...do.....	...do.....	31	117	...do.....	...do.....	45	185	...do.....	...do.....	53
50	...do.....	Sept. 12	32	118	...do.....	Oct. 6	50	186	Sept. 1	Oct. 14	43
51	...do.....	Sept. 14	34	119	...do.....	Oct. 14	58	187	Sept. 2	Oct. 26	54
52	...do.....	Sept. 16	36	120	...do.....	Oct. 18	62	188	Sept. 4	Oct. 19	45
53	...do.....	Sept. 17	37	121	...do.....	Oct. 20	64	189	...do.....	Oct. 20	46
54	...do.....	...do.....	37	122	...do.....	Nov. 1	76	190	...do.....	Oct. 23	49
55	...do.....	Sept. 19	39	123	Aug. 18	Sept. 19	32	191	...do.....	Nov. 13	70
56	...do.....	Sept. 26	46	124	...do.....	Sept. 28	41	192	...do.....	...do.....	70
57	...do.....	Oct. 10	60	125	...do.....	Sept. 29	42	193	...do.....	...do.....	70
58	...do.....	Oct. 11	61	126	...do.....	Oct. 3	46	194	Sept. 5	...do.....	69
59	Aug. 12	Sept. 7	26	127	...do.....	Nov. 10	84	195	Sept. 8	Oct. 19	41
60	...do.....	Sept. 11	30	128	Aug. 20	Sept. 13	24	196	Sept. 10	Oct. 20	40
61	...do.....	Sept. 12	31	129	...do.....	Sept. 19	30	197	...do.....	Nov. 10	61
62	...do.....	Sept. 13	32	130	...do.....	Sept. 22	33	198	...do.....	Nov. 13	64
63	...do.....	Sept. 14	33	131	...do.....	...do.....	33	199	Sept. 11	Oct. 26	45
64	...do.....	Sept. 18	37	132	...do.....	...do.....	33				
65	...do.....	...do.....	37	133	...do.....	...do.....	33				
66	...do.....	Sept. 19	38	134	...do.....	Sept. 26	37	Average			40.03
67	...do.....	...do.....	38	135	...do.....	...do.....	37	Maximum			84
68	...do.....	Oct. 7	56	136	...do.....	Sept. 28	39	Minimum			20

TABLE LXII.—*Length of feeding period of second-brood larvæ, Douglas, Mich., 1911; summary of Table LXI.*

Number of larvæ.	Days of feeding.	Number of larvæ.	Days of feeding.	Number of larvæ.	Days of feeding.	Number of larvæ.	Days of feeding.
1	20	7	32	4	44	2	56
1	21	9	33	8	45	2	58
4	22	5	34	5	46	1	59
5	23	4	35	2	47	1	60
6	24	13	36	3	48	3	61
2	25	9	37	3	49	1	62
5	26	9	38	4	50	2	64
2	27	4	39	3	51	2	69
4	28	8	40	2	52	3	70
7	29	7	41	3	53	1	71
3	30	3	42	3	54	1	76
10	31	8	43	2	55	2	84

Length of feeding period.—The feeding period of the second-brood larvæ is considerably longer than has been recorded for the first-brood larvæ and is mainly the result of prevailing low temperatures during the late summer and the fall. The data from 199 observations (Table LXI) cover a long period of time extending from July 23, when the earliest larvæ hatched, to November 13, when the last larvæ left the fruit. There was a range in the length of the feeding period of from 20 to 84 days, with an average of 40 days.

Time of maturity.—In the rearing cages the first larvæ of the second brood left the fruit August 18, but these were not from the earliest eggs. Considering the time of feeding and the date of earliest oviposition, it is evident that in the field the first larvæ left the fruit about August 13. As noted from the band records, the last larvæ left the fruit November 13, which was also the last date of observation in the rearing cages.

BAND RECORDS OF 1911.

During 1911 the band-record tests were extended to the following five localities: Benton Harbor, New Richmond, Douglas, lake shore (near Douglas), and Pentwater. The purpose of these tests in the widely separated sections of the Michigan fruit belt was to determine the possible existence of differences in the time of development of the codling moth.

The different band-record orchards were located respectively near Benton Harbor, 7 miles from the lake; at Douglas, on the grounds of the station 2 miles from the lake; at the lake shore, west of Douglas; and near Pentwater, about 7 miles from the lake. Most of the apple trees were old and none of them had been sprayed with poison. The number of trees and varieties of apples, so far as could be determined, were as follows: At Douglas, two trees Golden Russet, one Rhode Island Greening, one crab apple; at the lake shore, one King, two Canada Red, one Wealthy, one Astrachan, two winter varieties not determined; at New Richmond, two Baldwin, one Transcendent crab apple, one winter variety not determined; at Benton Harbor, one Golden Russet, one Canada Red, one crab apple, three fall varieties not determined; at Pentwater, six Ben Davis.

TABLE LXIII.—*Band records at Douglas, Mich., 1911.*

No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.	No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.
1	June 25	1	....	....	1	26	Sept. 8	9	....	....	9
2	June 28	2	2	....	0	27	Sept. 11	13	....	....	13
3	July 1	3	2	....	1	28	Sept. 14	11	....	....	11
4	July 4	0	....	....	0	29	Sept. 17	20	....	....	20
5	July 7	2	2	....	0	30	Sept. 20	17	....	....	17
6	July 10	15	5	1	9	31	Sept. 23	19	....	....	19
7	July 13	9	7	....	2	32	Sept. 26	20	....	....	20
8	July 16	21	14	6	1	33	Sept. 29	27	....	....	27
9	July 19	18	14	....	4	34	Oct. 2	8	....	....	8
10	July 22	21	20	1	0	35	Oct. 5	10	....	....	10
11	July 25	11	3	2	6	36	Oct. 8	6	....	....	6
12	July 28	13	5	4	4	37	Oct. 11	16	....	....	16
13	July 31	17	1	3	13	38	Oct. 14	10	....	....	10
14	Aug. 3	7	3	1	3	39	Oct. 17	17	....	....	17
15	Aug. 6	16	6	....	10	40	Oct. 20	8	....	....	8
16	Aug. 9	20	3	1	16	41	Oct. 23	2	....	....	2
17	Aug. 12	28	4	....	24	42	Oct. 26	1	....	....	1
18	Aug. 15	21	....	....	21	43	Oct. 29	0	....	....	0
19	Aug. 18	12	....	....	12	44	Nov. 1	6	....	....	6
20	Aug. 21	10	....	....	10	45	Nov. 4	0	....	....	0
21	Aug. 24	14	....	....	14	46	Nov. 7	0	....	....	0
22	Aug. 27	8	....	....	8	47	Nov. 10	2	....	....	2
23	Aug. 30	3	....	....	3	48	Nov. 13	1	....	....	1
24	Sept. 2	9	....	....	9						
25	Sept. 5	13	....	....	13		Total	517	91	19	407

At Benton Harbor, New Richmond, and Pentwater the larvæ were collected respectively by Miss Clara Jakway, Mr. G. W. Tibbits, and Mr. S. J. Taylor, who sent the collected larvæ for each observation to the station at Douglas. Mailing cases (see fig. 17) containing small blocks of corrugated pasteboard were used and proved very satisfactory. Very few larvæ were injured during transportation, and not a single shipment was lost during the whole season. At the Douglas and lake shore orchards the larvæ were collected by the staff of the station.

TABLE LXIV.—*Band records of 1911 at Benton Harbor, Mich.; larvæ collected by Miss Clara Jakway.*

No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.	No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.
1	June 25	12	4	1	7	24	Sept. 2	67	....	....	67
2	June 28	58	37	2	19	25	Sept. 5	53	....	....	53
3	July 1	71	47	8	16	26	Sept. 8	65	....	....	65
4	July 4	120	66	9	45	27	Sept. 11	37	....	....	37
5	July 7	103	52	1	50	28	Sept. 14	48	....	....	48
6	July 10	94	43	7	44	29	Sept. 17	32	....	....	32
7	July 13	61	45	3	13	30	Sept. 20	24	....	....	24
8	July 16	46	28	2	16	31	Sept. 23	15	....	....	15
9	July 19	36	30	....	6	32	Sept. 26	16	....	....	16
10	July 22	37	27	2	8	33	Sept. 29	8	....	....	8
11	July 25	20	16	....	4	34	Oct. 2	4	....	....	4
12	July 28	19	15	....	4	35	Oct. 5	4	....	....	4
13	July 31	22	9	....	13	36	Oct. 8	3	....	....	3
14	Aug. 3	20	6	....	14	37	Oct. 11	4	....	....	4
15	Aug. 6	28	1	....	27	38	Oct. 14	5	....	....	5
16	Aug. 9	44	....	....	44	39	Oct. 17	5	....	....	5
17	Aug. 12	41	8	....	33	40	Oct. 20	4	....	....	4
18	Aug. 15	57	3	....	54	41	Oct. 23	5	....	....	5
19	Aug. 18	59	1	....	58	42	Oct. 26	1	....	....	1
20	Aug. 21	60	2	....	58	43	Oct. 29	1	....	....	1
21	Aug. 24	42	....	....	42						
22	Aug. 27	49	1	....	48		Total	1,567	441	35	1,091
23	Aug. 30	67	....	....	67						

The results from the above band records are presented in Tables LXIII and LXVIII, in so far as same could be completed in 1911. The time of appearance of larvæ and their relative abundance in the respective localities have been graphically shown by curves in figures 18 and 19. It will be noted here that there is practically no difference in the time of appearance of the first larvæ in the five localities; nor is there any difference in the time of appearance of the earliest second-brood larvæ, so far as this could be determined. In accounting for this uniformity in time of maturity of larvæ it should be remembered that the seasonal conditions during 1911 were quite

FIG. 17.—Mailing case used for shipping codling-moth larvæ. (Original.)

unusual. The spring opened up suddenly and uniformly over the entire fruit belt, and the prevailing high temperature must have started the development of the insects more or less at the same time in the different sections. During 1910, it will be recalled that in these localities a slight difference was observed in the time and rate of appearance of the first brood of larvæ and practically no difference in the time of appearance of the second brood of larvæ. We may deduce from these observations that the seasonal development may in years become more uniform in the different sections of the fruit belt than is generally the rule, and that these differences are more in evidence during the early spring than during the rest of the season, while at midsummer conditions are more or less uniform for the whole belt.

TABLE LXV.—*Band records at New Richmond, Mich., 1911; larvæ collected by G. W. Tibbits.*

No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.	No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.
1	June 25	....	....	....	....	24	Sept. 2	7	....	....	7
2	June 28	12	11	....	1	25	Sept. 5	12	....	....	12
3	July 1	8	2	1	5	26	Sept. 8	8	....	....	8
4	July 4	6	2	....	4	27	Sept. 11	12	....	....	12
5	July 7	17	10	1	6	28	Sept. 14	12	....	....	12
6	July 10	18	10	4	4	29	Sept. 17	11	....	....	11
7	July 13	17	5	....	12	30	Sept. 20	14	....	....	14
8	July 16	21	7	....	14	31	Sept. 23	11	....	....	11
9	July 19	16	10	....	6	32	Sept. 26	16	....	....	16
10	July 22	19	11	1	7	33	Sept. 29	11	....	....	11
11	July 25	17	5	1	11	34	Oct. 2	4	....	....	4
12	July 28	7	4	1	2	35	Oct. 5	4	....	....	4
13	July 31	5	....	....	5	36	Oct. 8	3	....	....	3
14	Aug. 3	9	5	....	4	37	Oct. 11	5	....	....	5
15	Aug. 6	14	2	....	12	38	Oct. 14	4	....	....	4
16	Aug. 9	11	3	....	8	39	Oct. 17	4	....	....	4
17	Aug. 12	20	3	....	17	40	Oct. 20	1	....	....	1
18	Aug. 15	14	....	....	14	41	Oct. 23	3	....	....	3
19	Aug. 18	12	....	....	12	42	Oct. 26	1	....	....	1
20	Aug. 21	12	....	....	12	43	Oct. 29	1	....	....	1
21	Aug. 24	13	....	....	13	44	Nov. 1	1	....	....	1
22	Aug. 27	10	....	....	10						
23	Aug. 30	11	....	....	11		Total......	434	90	9	335

The band-record curves in figures 18 and 19 are of further interest in that they show a marked irregularity in the rate of appearance of larvæ in the different orchards, and none of the curves show any natural demarcation between the two broods of larvæ which could be used as a basis to separate the two broods.

TABLE LXVI.—*Band records at the lake shore near Douglas, Mich., 1911.*

No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.	No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.
1	June 25	0	....	....	0	26	Sept. 8	15	....	....	15
2	June 28	12	4	5	3	27	Sept. 11	25	....	....	25
3	July 1	11	8	1	2	28	Sept. 14	28	....	....	28
4	July 4	14	12	....	2	29	Sept. 17	28	....	....	28
5	July 7	57	32	....	25	30	Sept. 20	32	....	....	32
6	July 10	23	12	1	10	31	Sept. 23	26	....	....	26
7	July 13	19	15	....	4	32	Sept. 26	28	....	....	28
8	July 16	23	17	....	6	33	Sept. 29	17	....	....	17
9	July 19	49	25	....	24	34	Oct. 2	7	....	....	7
10	July 22	48	38	....	10	35	Oct. 5	11	....	....	11
11	July 25	38	31	1	6	36	Oct. 8	4	....	....	4
12	July 28	43	22	....	21	37	Oct. 11	12	....	....	12
13	July 31	44	26	....	18	38	Oct. 14	5	....	....	5
14	Aug. 3	43	19	1	23	39	Oct. 17	13	....	....	13
15	Aug. 6	59	15	....	44	40	Oct. 20	4	....	....	4
16	Aug. 9	44	9	....	35	41	Oct. 23	1	....	....	1
17	Aug. 12	53	....	....	53	42	Oct. 26	1	....	....	1
18	Aug. 15	42	2	....	40	43	Oct. 29	0	....	....	0
19	Aug. 18	32	....	....	32	44	Nov. 1	1	....	....	1
20	Aug. 21	34	....	....	34	45	Nov. 4	0	....	....	0
21	Aug. 24	27	....	....	27	46	Nov. 7	0	....	....	0
22	Aug. 27	28	....	....	28	47	Nov 10	2	....	....	2
23	Aug. 30	32	....	....	32						
24	Sept. 2	44	....	....	44		Total......	1,125	287	9	829
25	Sept. 5	46	....	....	46						

Some of the band records might even become misleading were they not supplemented by observations from the rearing experiments. For instance the great drop in the curve of the Benton Harbor record (fig. 19) was due to the exposed condition of the apple trees and to severe storms during the latter half of July. Owing to the dropping of over half of the apple crop that resulted, a large number of larvæ failed to reach the bands, and many immature larvæ

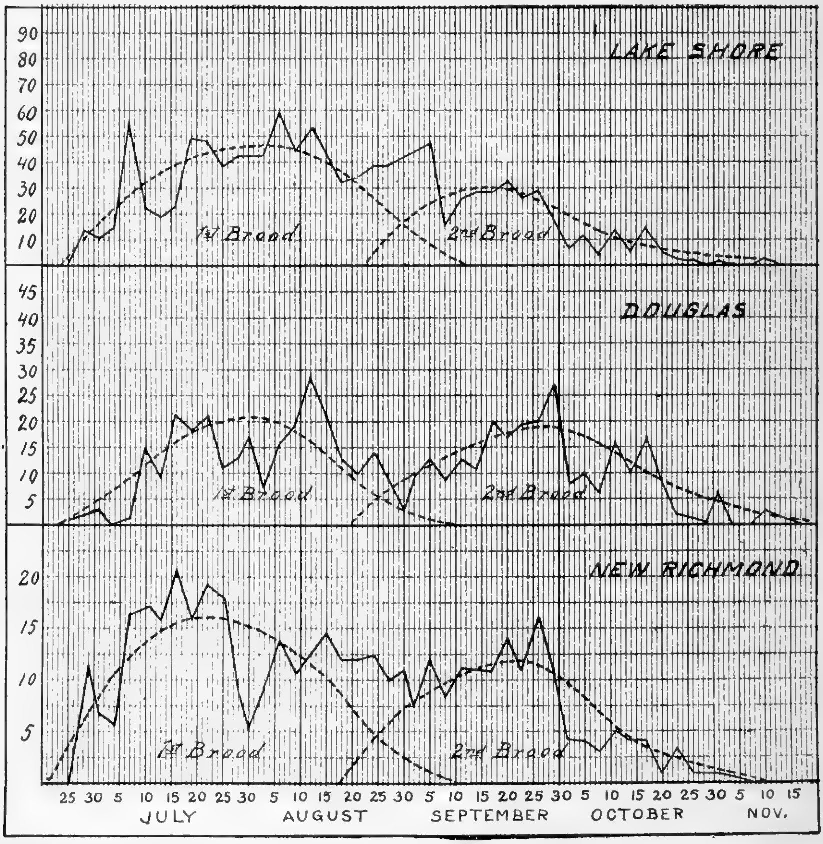


FIG. 18.—Curves made from band-record experiments in orchards at the lake shore near Douglas, at Douglas, and at New Richmond, Mich., 1911. (Original.)

were materially delayed in their normal growth in apples on the ground. There is also to be noted a marked difference in the relative abundance of first-brood and second-brood larvæ in the different localities. Of the total number of larvæ of the Douglas band records 50 per cent were of the second brood, while of the Pentwater records only 31 per cent pertained to the second brood. For a comparison of the details of the results for the five band records reference is made to Table LXVIII.

TABLE LXVII.—*Band records of 1911, at Pentwater, Mich.; larvæ collected by S. J. Taylor.*

No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.	No. of record.	Date of collecting.	Number of larvæ.	Emergence of moths, 1911.	Emergence of parasites, 1911.	Number of wintering larvæ.
1	June 25	6	1	....	5	27	Sept. 11	18	....	....	18
2	June 28	10	5	....	5	28	Sept. 14	12	....	....	12
3	July 1	56	44	2	10	29	Sept. 17	14	....	....	14
4	July 4	24	9	....	15	30	Sept. 20	16	....	....	16
5	July 7	18	11	....	7	31	Sept. 23	17	....	....	17
6	July 10	17	4	....	13	32	Sept. 26	22	....	....	22
7	July 13	37	31	....	6	33	Sept. 29	23	....	....	23
8	July 16	46	34	....	12	34	Oct. 2	13	....	....	13
9	July 19	57	38	....	19	35	Oct. 5	10	....	....	10
10	July 22	73	67	....	6	36	Oct. 8	5	....	....	5
11	July 25	38	29	....	9	37	Oct. 11	13	....	....	13
12	July 28	39	31	....	8	38	Oct. 14	11	....	....	11
13	July 31	52	25	....	27	39	Oct. 17	22	....	....	22
14	Aug. 3	45	21	....	24	40	Oct. 20	15	....	....	15
15	Aug. 6	38	11	....	27	41	Oct. 23	2	....	....	2
16	Aug. 9	32	5	....	27	42	Oct. 26	3	....	....	3
17	Aug. 12	16	2	....	14	43	Oct. 29	2	....	....	2
18	Aug. 15	42	4	....	38	44	Nov. 1	0	....	....	0
19	Aug. 18	28	....	....	28	45	Nov. 4	0	....	....	0
20	Aug. 21	26	....	....	26	46	Nov. 7	1	....	....	1
21	Aug. 24	17	....	....	17	47	Nov 10	0	....	....	0
22	Aug. 27	25	....	....	25	48	Nov. 13	0	....	....	0
23	Aug. 30	26	....	....	26	49	Nov. 16	0	....	....	0
24	Sept. 2	25	....	....	25	50	Nov. 19	1	....	....	1
25	Sept. 5	15	....	....	15						
26	Sept. 8	16	....	....	16		Total......	1,044	372	2	670

TABLE LXVIII.—*Band records of 1911; summaries of Tables LXIII–LXVII.*

Observations.	Douglas.		Lake shore.		New Richmond.		Benton Harbor.		Pentwater.		Average per cent.
	Total number.	Per cent.	Total number.	Per cent.	Total number.	Per cent.	Total number.	Per cent.	Total number.	Per cent.	
Larvæ collected from the bands	517	100.0	1,125	100.0	434	100.0	1,567	100.0	1,044	100.0	100.0
Moths emerging, 1911	91	17.6	287	25.5	90	20.7	441	28.1	372	35.6	25.5
Parasites emerging, 1911	19	3.7	9	.8	9	2.1	35	2.3	2	.2	1.8
Larvæ of the first brood	261	50.5	775	68.9	268	61.7	1,008	64.3	717	68.7	62.8
Transforming larvæ of first brood	91	34.9	287	37.0	90	33.6	441	43.7	372	51.9	40.0
Wintering larvæ of first brood	170	65.1	488	63.0	178	66.4	567	56.3	345	48.1	60.0
Larvæ of the second brood	256	49.5	350	31.1	166	38.3	559	35.7	327	31.3	37.2
Wintering larvæ of first and second broods	407	78.7	829	73.7	335	77.2	1,091	69.6	670	64.2	72.7

The averages for the different observations show that from the total number of larvæ only 25.5 per cent transformed and issued as moths in 1911; adult parasites issued in 1911 from 1.8 per cent of the codling-moth larvæ; 62.8 per cent of the larvæ were of the first brood and 37.2 per cent of the second brood; of the first-brood larvæ 40 per cent transformed and 60 per cent wintered; of both the first and second broods 72.7 per cent of the larvæ wintered.

SUMMARY OF SEASONAL-HISTORY STUDIES OF 1911.

The prevailing high temperature of the season produced a marked shortening in the time of development of the codling moth. The deviation from the average conditions is only slightly noticeable within the separate stages, but becomes strikingly marked for the

whole life cycle. Thus the time of hatching of the earliest larvæ of the second brood came 21 days ahead of those for the previous year, and the time of hatching of the second-brood larvæ extended over an unusually long period of two and a half months. The second-brood larvæ were exceptionally abundant, being in some orchards equal in numbers with those of the first brood. In figure 20 a summary is given in a graphical form to illustrate the progress of the development of the codling moth in the course of the whole season of 1911.

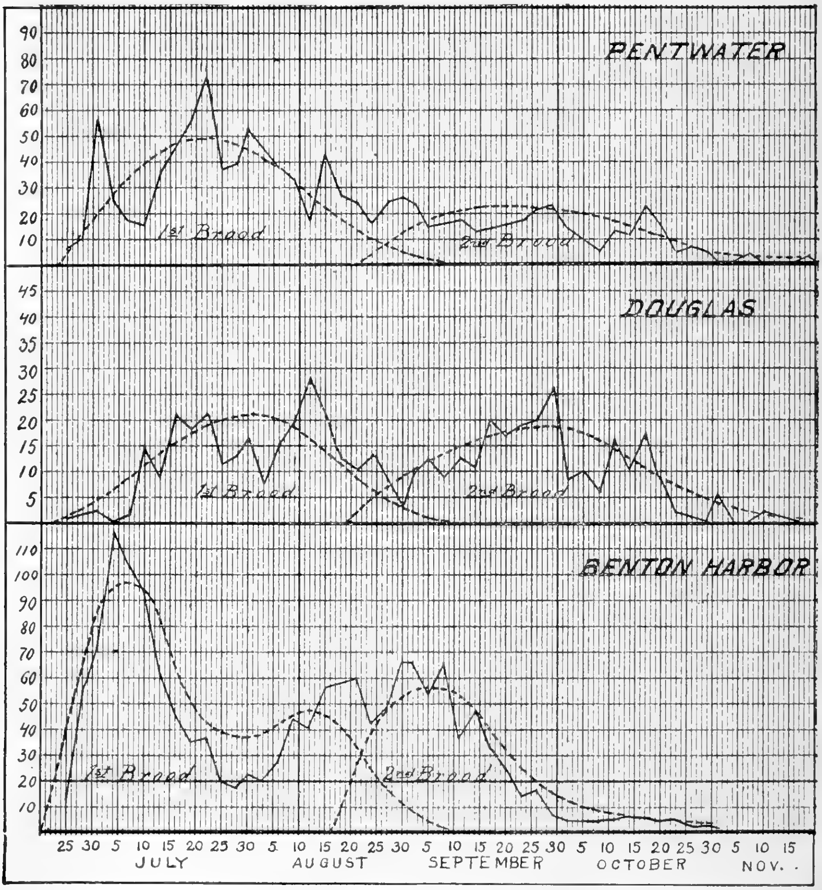


FIG. 19.—Curves made from band-record experiments in orchards at Pentwater, Douglas, and Benton Harbor, Mich., 1911. (Original.)

WEATHER RECORDS FOR 1909, 1910, AND 1911.

Considering the variation in the time of transformation of the codling moth during the three years of observation, it becomes evident that the insect is largely governed by climatic conditions. This is only natural, since phytophagous insects, depending upon the development of their host plants, must to a certain degree be governed by the same phenological laws that govern these plants. The earliest codling moths of the spring brood generally appear at a

time shortly after the blooming period of apple, so that the early larvæ will hatch after the setting of the young fruit. A full consideration of climatic conditions during the years 1909, 1910, and 1911 is therefore given for a better interpretation of the life-history studies.

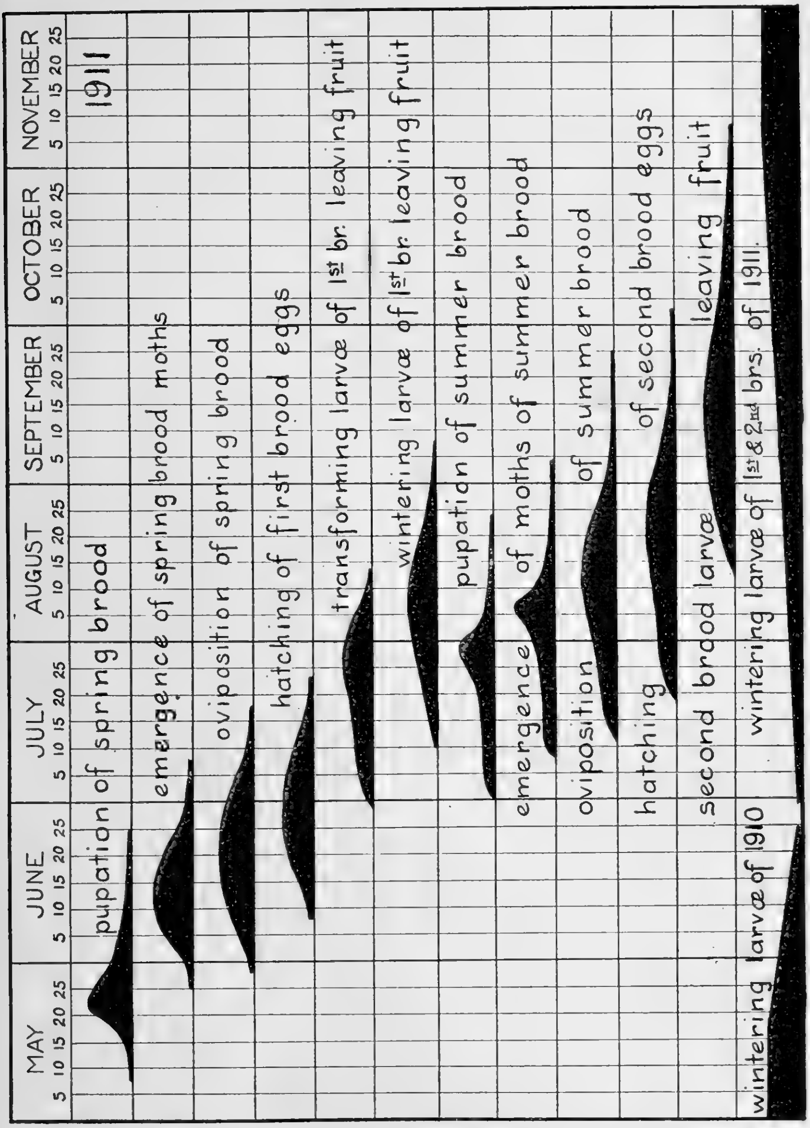


FIG. 20.—Diagram illustrating seasonal history of the codling moth as observed during 1911, at Douglas, Mich. (Original.)

A self-recording thermometer of the type generally used by the United States Weather Bureau was kept in the rearing shelter throughout the seasons of 1910 and 1911, and the records of the temperature conditions are given in Tables LXIX and LXX in degrees Fahrenheit. The average daily temperature in these tables represents the averages from hourly readings for each day. The readings

of maximum and minimum degrees of temperature were taken from a special maximum and minimum instrument. Daily record was also kept on the general weather conditions. For the preparation of the following account of climatic conditions the writer has in addition made extensive use of the reports of the United States Weather Bureau.

The season of 1909 was characterized by a cool and wet April, by heavy rains during July, and by an exceptionally warm November. During the month of May rather cold and dry weather prevailed. During June the temperature as a whole was seasonable, although there were an unusually large number of rainy days. The temperature for July averaged slightly below normal, and the precipitation was far in excess of normal. During August the temperature averaged several degrees above the normal and the rainfall was slightly in excess in the southern parts of the peninsula. September, on the contrary, was marked by a somewhat low temperature and a deficiency of precipitation, October was unseasonably cool and rather dry, while November as a whole was unusually warm.

The spring of 1910 in many of its features was unprecedented, as is well stated by the United States Weather reports for March:

> The excessive warmth, the extreme dryness both as regards precipitation and relative humidity, the large number of clear days with bright sunshine, the early disappearance of snow and ice, the light wind movement, and the absence of serious storms makes a history for the month (March) without parallel since the beginning of the official records. Never since the Weather Bureau was established has there been such an early opening spring. As a whole, the conditions that prevailed at the close of the month were those usually experienced from three to five weeks later.

The warm weather of March continued through the first two weeks of April, when many deciduous fruit trees were out in full bloom. Following this warm weather, at a very critical period for the orchards, a drop of temperature occurred, which was accompanied by a storm with rain and snow and severe freezing. The cool weather which prevailed during the latter half of April continued with slight interruption throughout the month of May and the first half of June. Vegetation was not merely greatly retarded, but badly damaged, and the season was exceptionally backward. In striking contrast to this low-temperature condition came warm weather, which was rather above normal, extending over the latter half of June and all of July. August was fairly normal. During these last months precipitation was below the average, and clear bright weather prevailed mostly throughout. The weather conditions during September and October were fairly normal. A marked drop in temperature set in during late October, which brought most insect activity to a standstill for the rest of the season. The month of November, in striking contrast with 1909, was cloudy and cold.

The uniform spring of 1911 was very favorable for the development of fruit and leaf buds, which were not unduly forwarded. The weather during April was rather more severe than usual until the last

week of the month, when a pronounced warm spell set in, which advanced rapidly the growth of vegetation. The mean temperature for May was decidedly above normal, and an abundance of sunshine prevailed. The United States Weather Bureau pronounced the heat for the month unprecedented. Thunderstorms were frequent, accompanied by high winds and excessive rainfall. This weather condition continued without interruption throughout the greater part of June, when severe storms occurred, which caused great damage to orchards and the fruit crop. During the period from the 11th to the 18th, at the height of the emergence period of the spring brood of moths, a markedly low temperature prevailed, accompanied by frequent rains, which caused a sudden and prolonged delay in the appearance of the moths. The weather conditions during July were also very exceptional. The first week of the month was marked by excessive heat and great dryness, while during the latter half of the month decidedly cold weather prevailed, with frequent local showers. August in most respects was normal, while September was marked by sharp alternation of warm and cold periods and a frequency of rainfalls. During October, and particularly during November, cool weather prevailed, which delayed considerably the time for the maturity of many second-brood codling-moth larvæ.

TABLE LXIX.—*Temperature records taken in the outdoor rearing shelter, showing maximum, minimum, and average daily temperatures, Douglas, Mich., 1910.*

Date.	April.			May.			June.			July.			August.			September.			October.			November.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F	°F	°F.	°F	°F	°F.	°F	°F	°F.
1..	61	39	49.9	64	48	54.5	51	41	45.2	87	59	72.5	74	56	68.2	70	50	59.5	65	44	58.0	50	38	46.9
2..	71	42	55.7	54	43	50.5	46	39	42.5	94	61	77.0	80	62	69.3	74	46	61.5	66	44	55.6	42	34	37.4
3..	68	48	59.0	54	40	45.3	54	42	46.7	81	62	71.1	78	66	72.5	72	62	66.4	83	58	68.2	44	28	35.5
4..	72	59	65.0	49	36	43.4	64	47	56.0	80	58	69.0	71	50	65.2	67	60	64.0	66	63	64.5	46	26	33.4
5..	74	50	64.6	53	33	43.8	58	44	51.8	86	54	70.4	72	50	63.3	72	64	70.4	72	57	65.0	40	32	36.0
6..	58	33	44.1	58	33	47.7	56	43	47.1	82	62	72.6	74	48	62.2	73	60	67.4	57	39	47.7	32	30	30.2
7..	41	30	36.0	60	38	53.0	57	44	49.9	77	60	69.6	75	56	64.6	81	54	69.0	62	34	47.8	46	31	37.0
8..	69	29	51.2	53	46	49.9	67	42	56.9	88	58	76.6	79	54	66.9	75	61	68.6	61	40	53.8	46	34	37.0
9..	59	43	49.7	60	41	49.5	74	53	63.7	89	65	74.2	74	64	69.6	60	42	54.6	58	44	51.7	56	40	48.5
10..	71	38	56.2	60	40	50.5	73	50	62.2	72	65	68.7	72	56	67.2	64	39	52.9	58	36	49.0	44	30	37.0
11..	58	35	50.0	54	36	44.8	66	50	56.4	81	67	73.4	77	50	64.2	77	43	62.5	66	54	61.2	36	30	32.7
12..	57	32	42.2	48	32	42.6	70	46	60.0	78	64	69.6	82	52	67.9	74	50	60.8	60	42	53.1	38	34	36.0
13..	59	29	45.0	47	34	40.9	78	53	64.0	76	56	67.0	81	59	70.1	64	46	53.6	69	40	53.9	39	33	35.2
14..	76	41	60.2	53	29	41.8	76	52	65.6	82	58	71.7	78	60	68.7	64	45	54.5	71	52	60.4	33	30	31.4
15..	73	61	67.2	65	37	51.5	73	54	64.7	82	68	75.0	84	63	73.4	70	43	56.7	61	50	55.2	34	31	32.9
16..	74	39	58.9	70	46	58.0	80	55	69.8	82	64	72.5	80	68	72.6	72	47	59.4	73	58	64.3	33	28	30.7
17..	52	37	43.1	58	47	53.6	80	67	73.1	77	58	67.7	80	64	72.3	66	52	60.3	78	52	62.0	30	28	28.2
18..	42	34	38.0	62	46	54.3	80	62	70.1	76	53	63.6	74	59	68.0	74	55	63.7	81	53	64.9	31	29	30.0
19..	45	39	40.9	71	52	61.3	74	60	68.3	76	51	64.0	76	53	63.9	68	53	57.7	78	58	66.9	38	24	29.4
20..	48	38	43.7	68	54	61.0	74	60	67.8	77	56	69.8	74	55	66.0	67	50	60.2	57	46	50.4	43	23	32.4
21..	62	34	46.9	77	54	62.3	87	65	76.6	79	65	72.3	83	60	73.4	74	49	59.5	53	46	49.4	36	30	33.0
22..	66	39	53.4	74	52	62.4	86	66	75.5	76	66	68.5	83	70	76.0	72	45	59.3	52	46	48.8	40	30	34.8
23..	37	31	32.8	62	45	52.8	86	72	75.7	84	66	74.2	78	63	70.7	66	57	60.0	61	39	48.4	47	32	38.5
24..	43	32	37.4	58	45	52.3	84	60	73.3	80	64	70.8	82	73	76.9	68	57	60.4	62	45	53.9	42	34	38.0
25..	42	36	38.9	56	43	48.5	84	55	69.5	79	62	71.1	78	58	68.4	57	48	54.7	58	40	50.1	40	30	36.1
26..	57	36	44.2	50	42	46.2	81	55	70.2	85	59	73.4	68	50	60.4	65	45	57.1	60	44	51.0	44	24	33.2
27..	54	40	45.6	60	39	50.4	74	61	67.8	77	64	70.2	71	48	60.8	58	53	55.1	50	34	42.6	38	32	34.1
28..	63	42	53.5	74	40	62.1	78	53	66.2	82	59	70.9	75	53	64.1	64	43	52.6	34	30	32.0	36	32	33.3
29..	74	56	65.2	62	46	54.5	80	56	69.9	80	61	72.8	76	58	67.0	66	42	55.0	35	30	31.8	31	28	29.8
30..	56	44	47.7	47	43	45.0	83	60	72.3	72	60	67.2	81	60	70.4	72	51	64.0	52	29	43.4	33	28	30.3
31..	....	....	....	42	40	41.0	....	....	....	72	48	62.3	76	59	66.3	....	....	....	58	32	47.4	....	....	....

NOTE.—The records from Apr. 1 to 20, inclusive, were taken from Mr. Tillinghast's records at Douglas, Mich.

TABLE LXX.—*Temperature records taken in the outdoor rearing shelter, showing maximum, minimum, and average daily temperatures, Douglas, Mich., 1911.*

Date.	May.			June.			July.			August.			September.			October.			November.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1...	58	32	41.5	70	49	61.0	89	67	79.2	76	66	70.8	83	55	69.5	54	50	51.8	41	28	35.3
2...	44	33	36.5	69	48	63.0	89	75	80.8	73	59	66.2	77	54	67.1	60	46	52.7	33	25	29.7
3...	52	35	42.9	80	60	66.9	92	73	81.2	76	55	66.3	70	49	59.8	69	44	54.0	41	30	34.2
4...	59	38	43.3	84	62	70.8	94	88	83.1	81	63	70.2	81	47	65.2	60	49	55.4	40	31	35.9
5...	59	31	43.6	75	52	65.2	95	78	86.0	85	69	73.7	75	61	65.7	50	37	46.7	48	38	41.8
6...	72	26	51.9	70	59	63.2	79	68	73.7	86	61	74.3	63	59	60.8	62	46	52.3	50	42	49.5
7...	74	43	59.7	68	54	60.8	85	65	74.4	88	64	77.0	73	57	62.2	55	36	46.0	44	40	41.8
8...	75	51	61.3	75	53	65.9	89	66	78.9	74	69	69.4	70	56	67.9	56	31	44.5	50	33	40.2
9...	76	55	62.4	84	62	75.3	89	73	79.7	84	57	70.7	64	53	60.1	63	38	49.6	47	33	41.3
10...	82	54	68.9	86	67	74.9	89	73	77.2	87	62	73.1	71	53	61.9	60	48	52.7	59	48	52.4
11...	64	55	60.3	78	64	66.2	87	71	78.2	78	64	67.4	73	58	64.9	60	46	52.0	72	46	62.4
12...	68	42	52.5	64	53	59.2	78	60	67.1	73	57	65.3	62	52	55.4	59	43	50.0	39	[1] 20	[1] 23.1
13..	65	36	48.5	66	51	58.8	78	59	70.8	78	60	67.0	67	48	56.3	64	42	51.9	25	[1] 20	[1] 23.2
14..	75	47	61.4	72	53	61.2	79	68	69.1	81	67	73.4	70	50	60.6	59	48	53.2	33	24	27.2
15..	79	55	68.7	72	53	63.3	82	57	70.6	76	67	69.6	72	61	66.2	63	47	53.0	34	26	30.4
16..	79	58	68.8	68	60	63.4	72	63	65.7	81	69	73.3	73	50	62.8	76	50	63.1	34	21	27.0
17..	79	64	71.9	69	60	62.3	72	54	61.9	77	67	70.9	82	53	68.5	57	42	53.7	48	30	35.5
18..	84	64	74.7	73	55	63.7	79	54	68.4	78	66	66.3	74	61	66.7	64	41	53.3	34	26	28.5
19..	86	72	79.2	78	55	68.1	75	64	67.7	69	51	60.0	64	48	59.2	54	46	50.2	32	27	29.8
20..	85	59	70.0	76	62	69.5	77	53	66.4	70	49	60.9	68	45	57.9	53	45	47.9	34	28	31.6
21..	74	61	69.8	79	55	70.1	72	64	66.0	80	53	68.5	68	47	56.3	51	43	45.9	34	28	31.3
22..	76	60	65.0	85	65	76.9	75	53	68.0	72	66	65.3	70	44	56.2	48	42	44.3	37	28	33.0
23..	70	60	61.4	87	67	77.3	76	56	63.7	71	51	59.9	72	50	62.4	46	42	44.5	38	28	32.6
24..	72	54	58.0	82	59	69.7	68	53	59.6	70	56	59.3	67	59	62.0	51	41	45.3	31	26	28.0
25..	82	57	70.3	80	69	73.1	66	53	59.8	72	45	57.9	60	50	56.9	57	41	47.4	39	30	34.7
26..	82	63	72.1	83	68	74.9	71	51	62.3	78	49	63.4	63	43	53.9	50	32	39.1	48	34	38.4
27..	89	64	78.2	77	67	68.6	77	49	64.2	79	59	68.5	68	47	61.0	44	30	35.3	47	32	38.6
28..	68	61	62.9	64	58	60.3	78	56	69.2	69	59	62.7	63	42	54.2	47	33	40.7	38	26	33.6
29..	74	55	64.5	74	48	63.1	78	61	63.3	66	46	55.7	62	47	53.9	51	42	46.5	32	21	27.7
30..	75	52	65.3	83	47	74.3	82	62	73.7	74	44	58.2	56	46	50.6	48	41	43.9	34	27	31.2
31..	67	58	60.0	....	....	.....	86	63	76.0	74	53	59.5	....	....	.....	44	38	40.1	....	....	.....

[1] Temperatures below 20° F. not recorded.

COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASONS OF 1909, 1910, AND 1911.

On considering the seasonal variations in the time of transformation and the relative abundance of the codling moth it is evident that the climatic conditions, and mainly the temperature, are the direct governing factors. Sometimes a scarcity of fruit may materially reduce the normal abundance of the codling moth. The effect of climatic variations upon the life of the insect is particularly noticeable in the spring, when the relative earliness of the season is followed by a corresponding change in the time of emergence of the moths. From the curves of figures 1, 6, and 14, which represent the time of emergence of the spring moths for the respective years of 1909, 1910, and 1911, with temperature records for the last two years, it will be noted that under prevailing uniform temperatures the emergence for the main portion of the moths becomes limited to a short period, as occurred in 1910, while on the other hand under fluctuating temperatures the emergence is very irregular and extends over a much longer period of time, as observed in 1911.

The time of the emergence of the earliest moths has closely followed the time of blossoming of apples and occurred from 5 to 10 days after the blossoms dropped (Baldwin apples). By adding to these figures the time of flight of the moths previous to oviposition and the time of incubation of the eggs it was found that fully three weeks elapsed before the hatching of the earliest larvæ of the first brood.

In 1909 the moths commenced to appear at a normal time, but were somewhat delayed in reaching a maximum of emergence. The season as a whole was fairly normal. The late fall, together with

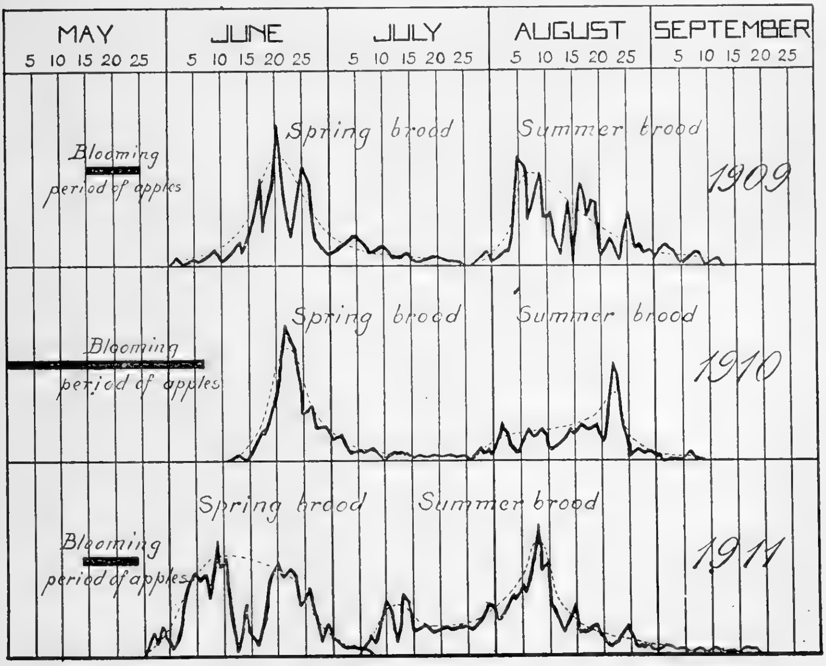


FIG. 21.—Diagram showing time of emergence and relative abundance of spring-brood and summer-brood codling moths, and blooming period of apple trees, during 1909, 1910, and 1911 at Douglas, Mich. (Original.)

other favorable influences, produced a development of a very large second brood of larvæ. Of the total number of larvæ for the year, 43 per cent were of the first brood and 57 per cent of the second brood. This occurrence was perhaps directly due to the unusual rate of emergence of the moths of the summer brood. These commenced to appear at the normal time, but already reached a maximum during the early part of August (fig. 21) instead of the latter part of the month, which is the general tendency as shown for 1910. In the band-record curves of figure 22 is shown a corresponding rate in the time of maturity of larvæ of the second brood. The maximum in the first brood of larvæ occurred comparatively late,

which in turn reduced the percentages of transforming larvæ as against the percentage of wintering larvæ of the same brood (see Table LXXI). The occurrence of an early maximum of larvæ in the second-brood larvæ was due to the early rate of emergence of the moths of the summer brood, and to favorable climatic conditions.

During 1910 the codling moths of the spring brood were delayed in the time of emergence of the earliest individuals. The larger number of moths, however, emerged very soon after the first appearance of moths, so that for the rest of the season the dates for the occurrence of the separate stages were about normal. The summer moths commenced to appear July 26 and reached a maximum of

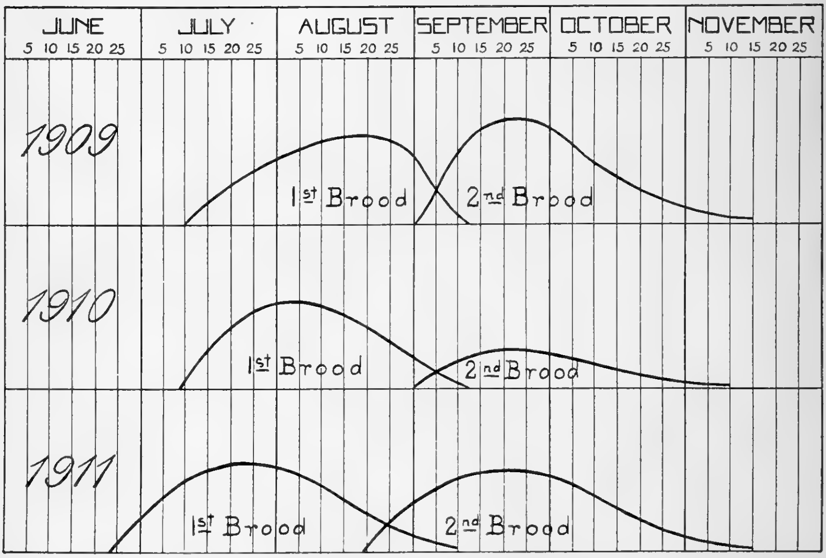


FIG. 22.—Diagram showing time of leaving the fruit by the first-brood and second-brood larvæ of the codling moth during 1909, 1910, and 1911, at Douglas, Mich. (Original.)

abundance during late August, which has been observed to be the general rate of emergence for the brood. In 1910 the codling moth was naturally limited in numbers as a result of the small crop of apples, and to this must be ascribed the reduced size of the second brood. Of the total number of larvæ from the band records, 73.2 per cent were of the first brood and only 26.8 per cent of the second brood. In some sections of the Michigan fruit belt the apple crop was so limited that only one brood occurred, the fruit having dropped before the second brood developed.

The spring of 1911 opened at a normal time. The temperature during the latter part of May and all of June was on an average exceptionally high, and this condition forwarded the development of both plants and insects in a very unusual manner. The moths commenced to emerge at a normal time, as compared with pheno-

logical developments. In the course of the emergence period part of the moths of the spring brood were hampered by cold rains, which set in during the middle of June and caused a somewhat prolonged delay for about one-half of the moths. This irregularity in the development of the insect produced an unusual effect upon the time and rate of occurrence of the separate stages for the rest of the season. This is noticeable from a study of the curves of figure 21 for 1911. In the summer brood there occurred an abundance of moths at the very start of the emergence, which was followed by a decrease in number as a result of the delay found in the spring brood; then again an abundance of moths appeared during the first half of August as a result of the emergence of the later half of the spring brood of moths. The prevailing high temperature advanced the earliest developing insects to the extent that the second-brood larvæ appeared three weeks ahead of those of 1910, and further prolonged to a very unusual extent the time of emergence of the summer moths, the period of egg deposition, and the period of hatching of the second brood of larvæ. The large fruit crop, together with the high temperature, favored the development of a large second brood of larvæ. For the total number of larvæ collected at the Douglas band records 50.5 per cent were of the first brood and 49.5 per cent of the second brood.

TABLE LXXI.—*Summary of results of band records for 1909, 1910, and 1911, at Douglas, Mich.*

Observations.	Percentages for—		
	1909	1910	1911
Moths emerging the same season	13.2	25.5	17.6
Moths emerging the following season	55.7	39.7	....
Total emergence of moths	68.8	65.2	....
Wintering larvæ of total band collection	85.7	73.5	78.7
Wintering larvæ killed by frost	24.6	30.1	....
Parasitized larvæ	6.6	4.7	....
Relative proportion of first-brood larvæ	43.1	73.2	50.5
Relative proportion of second-brood larvæ	56.9	26.8	49.5
Transforming larvæ of first brood	33.2	34.8	34.9
Wintering larvæ of first brood	66.8	65.2	65.1

The results from the band records for the three years at Douglas show that of the first-brood larvæ about one-third transformed the same season and two-thirds passed the winter in the larval stage, as do all second-brood larvæ. (See Table LXXI.)

INSECT ENEMIES.[1]

PREDACEOUS INSECTS.

Several predaceous insects have been found to attack the larvæ and pupæ of the codling moth. Of these a small black beetle and its larva, *Tenebroides corticalis* Melsh. (Pl. III, figs. 4, 5), belonging to

[1] For information relative to the bird enemies of the codling moth, see Yearbook of the Department of Agriculture for 1911, pp. 199–208, "Bird Enemies of the Codling Moth," by W. L. McAtee.

the family Trogositidæ, has been found to constitute one of the most important predatory insect enemies of the codling moth. The slender and flat form of the larva and also the depressed shape of the beetle enable the insect to penetrate into narrow cracks and crevices in search of prey. Both the larvæ and beetles have been found in the cocoons of the codling moth, having penetrated the walls of the same and destroyed the host. Full-grown larvæ and beetles have been collected in the late fall and in the spring, which would indicate that the insect passes the winter in both stages. The white and delicate pupa was once observed under the bark in a small cavity, which must have been made by the larvæ previous to pupation.

There are several species of carabid beetles that have been found under the bands on apple trees. Of these *Pinacodera limbata* Dej. (Pl. III, fig. 3) and *Platynus placidus* Say were seen to destroy the larvæ of the codling moth. Mr. W. Postiff collected in 1910 one specimen of *Tenebroides castanea* Melsh., which also was destructive to codling moth larvæ. These specimens were kindly determined by Mr. E. A. Schwarz, of the Bureau of Entomology.

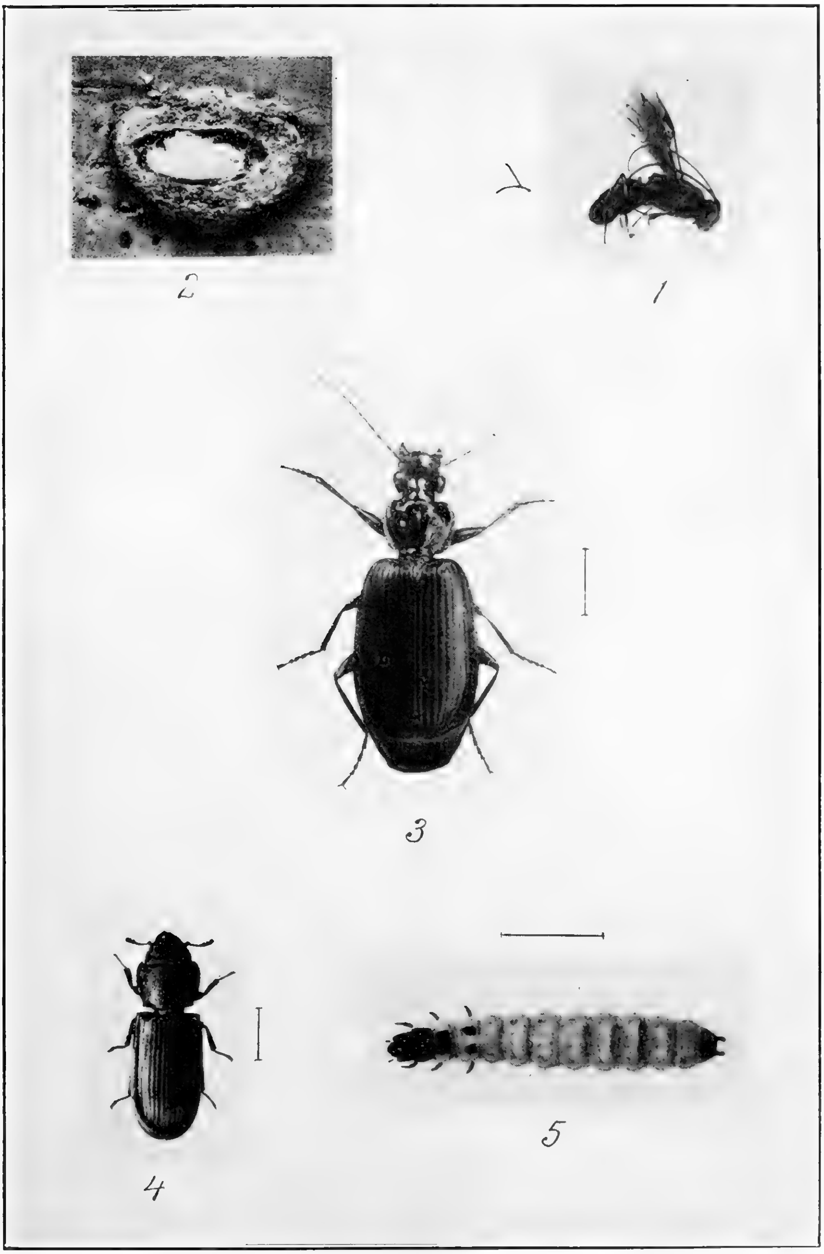
In wind fallen apples the codling moth larvæ are sometimes attacked by wireworms (species not determined), which have been found in wormy fruit. In confinement the wireworm larvæ fed freely upon codling moth larvæ, even after the latter were removed from the fruit.

The larvæ of a lacewing fly (*Chrysopa* sp.) were often observed in the act of absorbing the contents of the eggs of the codling moth. In the rearing shelter these insects were regular pests, in that they would destroy the eggs in the cages under observation whenever the eggs were left exposed. In the orchards the larvæ of the lacewing flies are very common and no doubt they play there an important rôle in checking the codling moth.

PARASITIC INSECTS.

Among the native hymenopterous parasites of the codling moth *Ascogaster* (*Chelonus*) *carpocapsæ* Vier. (Pl. III, figs. 1, 2) is the most commonly observed. It has been collected in the States of Michigan, Pennsylvania, Maryland, Virginia, and Nebraska, and will probably be found in most localities where the codling moth occurs. The species was originally described by Mr. H. L. Viereck [1] from specimens collected at Douglas, Mich., in 1908 by Mr. R. W. Braucher. The writer also reared the insect in abundance at North East, Pa., in 1908 and 1909. The band records in 1909 at Douglas, Mich., showed that 6.6 per cent of the codling moth larvæ were parasitized, and in 1910 the separate band records showed the following extent of parasitism: New Richmond, 7.7 per cent, Saugatuck 4.7 per cent, and Lake Shore 7.25 per cent.

[1] Proc. Ent. Soc. Wash., vol. 11, p. 43, 1909.



INSECT ENEMIES OF THE CODLING MOTH.

FIG. 1.—*Ascogaster carpocapsæ*, a hymenopterous parasite of codling-moth larvæ. Fig. 2.—Cocoon of *Ascogaster carpocapsæ* within a cocoon of the codling moth, enlarged twice. Fig. 3.—*Pinacodera limbata*, a predaceous beetle destructive to codling-moth larvæ. Figs. 4, 5.—*Tenebroides corticalis*, beetle and larva, which feed upon the larva and pupa of the codling moth. (Original.)

The time of emergence of the adult parasites coincides with the time of emergence of the two broods of the codling moth. (Tables LXXII and LXXIII.) Like the host, the parasite is evidently two-brooded or possibly has a partial second brood.

TABLE LXXII.—*Time of emergence of the spring brood and the summer brood of Ascogaster carpocapsæ at Douglas, Mich., 1910.*

SPRING BROOD.

Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.
2	June 22	9	June 27	4	July 2	1	July 9
9	June 23	2	June 28	1	July 3	1	July 15
5	June 24	14	June 29	5	July 5		
11	June 25	5	June 30	3	July 6	86	
10	June 26	3	July 1	1	July 8		

SUMMER BROOD.

Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.
1	July 26	2	Aug. 11	1	Aug. 19	3	Aug. 29
1	July 30	3	Aug. 12	5	Aug. 20	1	Aug. 30
2	Aug. 2	3	Aug. 13	6	Aug. 22	2	Sept. 5
5	Aug. 4	3	Aug. 14	2	Aug. 23		
1	Aug. 5	6	Aug. 15	2	Aug. 24	72	
3	Aug. 7	4	Aug. 16	3	Aug. 25		
2	Aug. 8	3	Aug. 17	1	Aug. 26		
4	Aug. 10	2	Aug. 18	1	Aug. 27		

TABLE LXXIII.—*Time of emergence of spring and summer broods of Ascogaster carpocapsæ at Douglas, Mich., 1911.*

SPRING BROOD.

Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.
1	June 2	3	June 12	3	June 19	2	June 28
4	June 5	2	June 13	7	June 20	1	June 29
7	June 6	4	June 14	4	June 21	1	June 30
1	June 8	5	June 15	2	June 22		
4	June 9	2	June 16	6	June 23	83	
7	June 10	4	June 17	4	June 24		
1	June 11	7	June 18	1	June 26		

SUMMER BROOD.

Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.	Number of parasites.	Date of emergence.
1	July 9	6	July 21	5	Aug. 4	1	Aug. 15
3	July 11	1	July 23	1	Aug. 6	2	Aug. 16
1	July 12	2	July 26	1	Aug. 7	1	Aug. 17
3	July 13	2	July 28	4	Aug. 8	1	Aug. 18
2	July 14	2	July 30	2	Aug. 9	1	Aug. 20
2	July 15	5	July 31	1	Aug. 10	2	Aug. 22
4	July 16	1	Aug. 1	2	Aug. 11	2	Aug. 27
1	July 17	2	Aug. 2	1	Aug. 13	1	Sept. 3
2	July 19	1	Aug. 3	5	Aug. 14		
						74	

The time and stage of the development when the codling moth larvæ become parasitized are not definitely known. Probably many larvæ are parasitized after they leave the fruit and while in search of suitable places for the spinning of their cocoons. It is very evident that many larvæ are parasitized while still in the fruit, since adult

parasites have been obtained from codling moth larvæ which were collected in windfallen fruit and confined in cages. At the time the parasitized codling moth larvæ leave the fruit they may readily be recognized by their inferior size and the absence of the pink color, which is characteristic of the full-grown codling moth larvæ. In the orchard on the grounds of the station, where numerous adult parasites had been liberated in the course of the season of 1911, fully 40 per cent of the band-record larvæ were parasitized in the late fall. The average measurement of the head of full-grown codling moth larvæ is 1.5 mm.; the parasitized larva at the time of leaving the fruit has an average head measurement of only 1.3 mm. In the spring of 1911, 15 undersized larvæ, lacking the pink color, were confined in a separate cage; of these, 10 proved later to be parasitized, while the rest died from other causes.

The parasite passes the winter in the larval stage within the host. The following spring feeding is terminated, and the host larva is completely devoured, except for the skin and the chitinous parts of the head. Within the cocoon of the host the parasite larva makes a small oval cocoon, white in color, within which it pupates shortly after. In 1911 one parasite pupated May 21 and issued as adult May 28, having remained 7 days in the pupal stage. So far as has been observed, only a single parasite develops in each host larva.

The parasitized codling moth larvæ that winter do not modify the cocoon in the spring as does the normal larva, which provides an exit for the issuing moth. The parasite fly is therefore forced to gnaw its way out through the walls of the cocoon.

NEMATODE WORMS.

On September 1, 1910, the writer collected a windfallen apple with a full-grown codling moth larva which was found to be infested with minute, white-colored nematode worms (species not determined). The entire body cavity of the larva was filled with the worms and quite a number of worms were also found in the burrows in the apple, where the mass of worms had the general appearance of mildew growth.

MISCELLANEOUS OBSERVATIONS.

NUMBER OF LARVAL INSTARS AND MOLTS OF THE CODLING MOTH.

The codling moth, like all arthropods possessing an exoskeleton, must shed the skin from time to time in the course of its growth. The process of casting the skin is called "molting" (ecdysis) and the stages between the molts are termed "instars."

The determination of the number of instars of the codling moth becomes difficult because of the small size of the larva in the early

stages and its habit of feeding within the fruit, where it can not readily be located for observation without great care and labor. Mr. E. L. Jenne,[1] in his studies of the codling moth in the Ozarks, determined the number of molts of the larvæ by rearing them on small pieces of fruit in glass vials. The vials were frequently examined for the cast skin of the head, and on this basis the number of molts was established. Jenne encountered great difficulty in preventing the fruit from rotting and in maintaining the larvæ in a healthy condition. His records from 12 larvæ showed that 9 larvæ passed through 7 instars and 3 larvæ passed through 8 instars.

At Douglas, Mich., the writer, in determining the larval molts, made use of Dyar's[2] method of head measurements, on the basis that "the widths of the head of the larva in its successive stages follow a regular geometrical progression." By this method the necessity of finding the cast skin was eliminated and the larvæ could be reared in entire fruit or in large pieces of fruit. On the other hand, this practice involved a considerable amount of labor and additional difficulties both in the finding of the larvæ and the taking of the measurements.

TABLE LXXIV.—*Instars of the codling moth larvæ of the second brood, and head measurements in millimeters for each instar, Douglas, Mich., 1910.*

No. of observation.	First instar.		Second instar.		Third instar.		Fourth instar.		Fifth instar.	
	Hatching.	Mm.	First molt.	Mm.	Second molt.	Mm.	Third molt.	Mm.	Fourth molt.	Mm.
1	Aug. 11	0.33	Aug. 15	0.50	Aug. 22	0.66	Aug. 27	1.00	Sept. 8	1.40
2	Aug. 12	.33	Aug. 16	.45	Aug. 20	.66	...do.....	1.03	[3]	......
3	...do.....	.33	...do.....	.50	Aug. 23	.63	Sept. 5	1.00	Sept. 1	1.30
4	Aug. 16	.33	Aug. 21	.48	Aug. 27	.66	[3]	.91	Sept. 12	1.20
5	...do.....	.33	...do.....	.55	Aug. 25	.73	[3]	......	......	......
6	...do.....	.33	...do.....	.55	...do.....	.70	[3]	......	......	......
7	...do.....	.33	...do.....	.46	[3]	......	......	......	......	......
8	...do.....	.33	...do.....	.50	Sept. 1	.70	[3]	......	......	......
9	Aug. 20	.33	Sept. 3	.40	Sept. 7	.65	Sept. 22	.87	[3]	......
10	...do.....	.32	Sept. 1	.48	Sept. 5	.65	Sept. 12	.83	Sept. 21	1.06

No. of observation.	Sixth instar.		Pupation.	Days duration of instars.					
	Fifth molt.	Mm.	Sixth molt.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.
1	Sept. 20	1.60	Pupation following spring.	4	7	5	12	12	Wintering.
2	......	......		4	4	7	......	......	
3	Sept. 18	1.53		4	7	4	5	17	
4	Sept. 22	1.50		5	6	9	7	10	
5	......	......		5	4	......	......	......	
6	......	......		5	4	......	......	......	
7	......	......		5	......	......	......	......	
8	......	......		5	11	......	......	......	
9	......	......		14	4	15	......	......	
10	[4]	......		12	4	7	9	[1]	

[1] Bul. 80, Part I, Bur. Ent., U. S. Dept. Agr., 1909.
[2] Psyche, vol. 5, p. 420.
[3] Died.
[4] Wintered.

TABLE LXXV.—*Larval instars of the codling moth; head measurements in millimeters for each instar; duration of instars. Summary of Table LXXIV.*

Observations.	Head measurements in mm. per instar.						Days duration of instars.					
	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.
Average	0.33	0.48	0.67	0.94	1.24	1.54	6.3	5.7	7.9	8.2	13.0	(1)
Maximum	.33	.55	.73	1.03	1.40	1.60	14	11	15	12	17	(1)
Minimum	.32	.40	.63	.83	1.06	1.50	4	4	4	5	10	(1)

[1] Winter.

The head measurements were all made by an ocular micrometer of a compound microscope. It was necessary to bring the larvæ to a perfectly quiet position before the readings could be made. In 1910 this was accomplished by placing a cover glass over the larvæ during the early stages. The larger larvæ were held in place between two broken pieces of glass and by a small glass cover placed above. The results of these readings are given in Table LXXIV. Four larvæ out of 10 reached maturity and entered their winter cocoons. Three of these passed through six instars and one larva passed through five instars. A summary of these readings has been brought together in Table LXXV. The average length of the entire feeding period was evidently prolonged beyond that of the normal. The records for the minimum length of time of each instar represent more nearly the normal.

In 1911 similar observations were again made for both first-brood and second-brood larvæ. To quiet the larvæ for the necessary readings they were held over a piece of ice under the microscope. The exposure of the larvæ to the ice was made as brief as possible and in most instances extended to a few seconds. It was found that the larvæ would resume their normal activities within a minute after the exposure, and this treatment seemed to have no material effect upon the larvæ so far as altering the normal numbers of molts, since the results of these tests are identical with those of 1910.

Table LXXVI.—*Observations on the instars of the first-brood codling-moth larvæ at Douglas, Mich., 1911.*

Number of observation.	Date of hatching and molting, and larval head measurements in millimeters.									
	First instar.		Second instar.		Third instar.		Fourth instar.		Fifth instar.	
	Hatched.	mm.	First molt.	mm.	Second molt.	mm.	Third molt.	mm.	Fourth molt.	mm.
1	June 19	0.35	June 26	0.46	July 1	0.66	July 5	0.83	July 9	1.10
2	...do...	.35	June 27	.45	....	.65	July 6	.88	...do...	1.30
3	June 27	.35	July 3	.50	July 6	.68	July 11	.90	July 16	1.18
4	June 28	.35	...do...	.49	...do...	.70	July 9	[1]1.10	July 13	[1]1.50
5	...do...	.35	....	....	July 9	.60	July 11	.85	July 17	1.15
6	...do...	.35	July 4	.46	July 8	.65	...do...	.85	...do...	1.15
7	July 2	.35	July 6	.46	July 9	.70	....	....	July 12	1.30
8	...do...	.35	...do...	.49	...do...	.65	July 24	.80	Aug. 1	1.08
9	...do...	.35	....	....	July 11	.62	July 17	.81	....	....
10	June 7	.35	July 10	.46	July 14	.60	....	....	....	....
11	....	....	....	....	July 15	.70	July 19	1.00	....	....
12	....	....	....	....	July 14	.65	July 20	.89	July 28	1.19
13	....	....	....	....	...do...	.70	July 18	1.08	....	....
14	....	....	....	....	....	....	....	....	July 14	1.00

No. of observation.	Date of hatching and molting, and larval head measurements in millimeters—Continued.				Days duration of instars.				
	Sixth instar.			Pupation, sixth molt.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.
	Fifth molt.	mm.	Loft fruit.						
1	July 13	1.40	....	....	7	5	4	4	4
2	....	....	Aug. 2	Aug. 8	8	....	....	3	[1]30
3	July 20	1.50	July 27	Aug. 4	6	3	5	5	4
4	....	....	July 23	July 31	5	3	3	4	[1]18
5	July 29	1.46	Aug. 5	Aug. 12	....	....	2	6	12
6	July 20	1.46	July 27	Aug. 4	6	4	3	6	3
7	July 29	1.57	Aug. 10	....	4	3	....	....	[1]17
8	Aug. 22	[1]1.19	[1]Aug. 30	[1]1.29	4	3	[1]15	8	[1]21
9	....	....	....	....	....	....	6	....	....
10	....	....	....	....	3	4	....	....	....
11	July 28	1.51	July 31	....	....	....	4	....	....
12	Aug. 6	1.46	....	....	....	....	6	8	9
13	July 25	1.50	Aug. 4	Aug. 8	....	....	4	....	....
14	July 19	1.50	July 27	Aug. 1	....	....	....	....	5

No. of observation.	Days duration of instars—Continued.				Remarks.
	Sixth instar.			Total larval life.	
	Feeding.	In cocoon.	Total.		
1	....	....	....	....	Died in sixth instar.
2	....	....	....	....	Moth emerged Aug. 21; below average size.
3	7	8	15	50	Moth emerged Aug. 19; below average size.
4	....	....	....	33	Moth emerged Aug. 13; below average size.
5	7	7	14	45	Moth emerged Aug. 25; average size.
6	7	8	15	37	Moth emerged Aug. 16; below average size.
7	12	....	....	....	Normal size; larvæ wintered.
8	....	....	....	59	Deformed; died Sept. 9.
9	....	....	....	....	Deformed; died July 24.
10	....	....	....	....	Died July 18.
11	[1]3	....	....	....	Died before pupation.
12	....	....	....	....	Moth emerged Aug. 21; normal size.
13	10	4	14	....	Died Aug. 20.
14	8	5	13	....	Moth emerged Aug. 12; normal size.

[1] Abnormal and not included in the summary.

Table LXXVII.—*Larval instars of the codling moth; head measurements in millimeters for each instar; days duration of instars. Summary of Table LXXVI.*

Observations.	Head measurements in mm. per instar.						Days duration of instars.							
	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar. Feeding.	Sixth instar. In cocoon.	Total larval life.
Average	0.35	0.47	0.66	0.89	1.16	1.47	5.6	3.6	4.1	5.5	6.1	8.3	6.4	44.8
Maximum	.35	.50	.70	1.08	1.30	1.57	8	5	6	8	12	12	8	59
Minimum	.35	.45	.60	.80	1.00	1.40	3	3	2	3	3	7	4	33

In the course of these studies there was a rather high percentage of mortality, but this was mainly due to the difficulty in properly removing the larvæ from the fruit.

Table LXXVIII.—*Instars of the codling moth larvæ of the second brood; head measurements in millimeters; days duration of the instars; Douglas, Mich., 1911.*

No. of observations.	Date of hatching and molting, and larval head measurements in millimeters.									
	First instar.		Second instar.		Third instar.		Fourth instar.		Fifth instar.	
	Hatched.	mm.	First molt.	mm.	Second molt.	mm.	Third molt.	mm.	Fourth. molt.	mm.
1	July 29	Average 0.35 mm.	Aug. 2	0.45	Aug. 6	0.75	Aug. 11	0.81		
2	...do		Aug. 3	.45	Aug. 7	[1] 1.00	Aug. 12	[1] 1.22		
3	...do		...do	.49	Aug. 8	.78				
4	...do		...do	.54	Aug. 6	.76				
5	Aug. 2		Aug. 7	.46	Aug. 13	.75				
6	...do		Aug. 8	.46	Aug. 15	.70				
7	Aug. 6		Aug. 10	.43						
8	...do		...do	.49						
9	...do								Aug. 18	1.22
10	Aug. 7				Aug. 20	.66	Aug. 27	[1] 1.08	Sept. 2	[1] 1.51
11	Aug. 11					.76	...do	[1] 1.19	Aug. 31	[1] 1.51
12	Aug. 12		Aug. 20	.50						
13	...do		Aug. 17	.46	Aug. 25	.68				
14	...do		...do	.46	Aug. 24	.67	Sept. 1	.81		
15	...do		Aug. 28	.50						
16	...do		Aug. 26	.49	Aug. 28	.71				
17	Aug. 14		Aug. 23	.49	...do	.66	Sept. 7			
18	...do		Aug. 19	.51	...do	.67				
19	Aug. 15		...do						Sept. 1	1.19
20	Aug. 16		Aug. 25	.50	Sept. 2	.67				
21	Aug. 18		Aug. 28	.42						
22	...do		Aug. 25	.46	Sept. 2	.60				
23	Aug. 24						Sept. 8	.80	Sept. 15	1.08
24	...do						...do	.81	Sept. 18	1.08

[1] Abnormal and not included in the summary.

TABLE LXXVIII.—*Instars of the codling moth larvæ of the second brood; head measurements in millimeters; days duration of the instars; Douglas, Mich., 1911*—Contd.

No. of observations.	Date of hatching and molting, and larval head measurements in millimeters—Continued.				Days duration of instars.						
	Sixth instar.			Pupation, sixth molt.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	
	Fifth molt.	mm.	Left fruit.							Feeding.	Wintering.
1				Pupation the following spring.	4	4	5				
2					5	4	5				
3					5	5					
4					5	3					
5					5	6					
6					6	7					
7					4						
8					4						
9	Aug. 26	1.81	Aug. 31						8	5	(2)
10			Sept. 18				7	6	(2)		
11			Sept. 10					4	(2)		
12					8						
13					5	8					
14					5	7	8				
15					16						
16					14	2					
17					9	5	10				
18					5	9					
19	Sept. 6	1.57	Sept. 18						5	12	(2)
20					9	8					
21					10						
22					7	8					
23	Sept. 27	1.62	Oct. 20					7	12	23	(2)
24	Oct. 1	1.52	Oct. 18					10	13	17	(2)

[1] Abnormal and not included in the summary.

[2] Wintered.

TABLE LXXIX.—*Larval instars of the codling moth; head measurements in millimeters for each instar; duration of instars; summary of Table LXXVIII.*

Observations.	Head measurements in mm. per instar.						Days duration of instars.					
	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth (feeding).
Average	0.35	0.47	0.70	0.81	1.14	1.63	7	5.8	7	7	9.5	14.2
Maximum		.54	.78	.81	1.08	1.81	16	9	10	10	13	23
Minimum		.42	.60	.80	1.22	1.52	4	2	5	4	5	5

The records for the time of molting and the head measurements for the separate instars for the first brood are given in Table LXXVI. Of a total number of 14 larvæ, 8 attained full growth. Of these, 2 passed through five instars and 6 through six instars. A single larva (No. 8) that appeared stunted in its growth had seven instars, but failed to reach maturity. One full-grown larva of this brood wintered, while 7 resulted in moths the same year. Larvæ Nos. 11 to 14, inclusive, were left undisturbed during their early stages in order that their development should not be unduly delayed.

The observations on the molting habits of the second brood of larvæ (Table LXXVIII) were not all completed, as at times some of the larvæ were neglected on account of the stress of other work.

TABLE LXXX.—*Head measurements of first-brood and second-brood codling moth larvæ, collected from banded trees at Douglas, Mich., 1911.*

No. of larvæ.	First brood larvæ, collected July 13.	No. of larvæ.	Second brood larvæ, collected Sept. 17.	No. of larvæ.	First brood larvæ, collected July 13.	No. of larvæ.	Second brood larvæ, collected Sept. 17.
	mm.		*mm.*		*mm.*		*mm.*
1	1.70♂	1	1.57♂	16	1.62♂	16	1.78♂
2	1.50♀	2	1.62♂	17	1.83♀	17	1.73♂
3	1.56♂	3	1.84♀	18	1.51♂	18	1.73♂
4	1.70♀	4	1.78♀	19	1.80♀	19	1.62♂
5	1.70♂	5	1.57♀	20	1.62♂	20	1.73♀
6	1.62♂	6	1.84♀	21	1.56♂	21	1.73♀
7	1.56♀	7	1.68♀	22	1.62♀	22	1.78♂
[1] 8	1.29♀	8	1.62♂	23	1.67♀	23	1.78♂
9	1.62♀	9	1.78♀	24	1.62♂	24	1.62♂
10	1.70♂	10	1.84♀	25	1.70♀	25	1.89♀
11	1.79♂	11	1.68♂	26	1.70♂	26	1.78♀
12	1.56♀	12	1.68♂	27	1.62♂	[1] 27	1.27♀
13	1.62♂	13	1.68♀	28	1.62♀	28	1.67♂
14	1.56♂	[1] 14	1.29♀	29	1.80♀	29	1.67♀
15	1.56♀	15	1.73♀	30	1.65♀	30	1.89♂

[1] Parasitized larvæ.

The results from these observations are, however, similar to those previously obtained.

The pink color which is characteristic of the mature larva first appeared a few days after the final molt. A number of mature first and second brood larvæ collected in the field were measured for a comparison with those maturing in the laboratory. The records of Table LXXX show no material difference in the size of head of the larvæ of the two sets except that the field larvæ are slightly larger, which is to be expected, since the latter have developed normally and without any interference.

TABLE LXXXI.—*The average widths of the head of the larva in its successive instars and the rate of increase at each molt; summary of Tables LXXIV–LXXIX.*

Instars.	1910, second brood.	1911, first brood.	1911, second brood.	Average.	Average increase at each molt.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
First	0.33	0.35	0.35	0.34	0.13
Second	.48	.47	.47	.47	.20
Third	.68	.66	.70	.67	.21
Fourth	.94	.89	.81	.88	.30
Fifth	1.24	1.16	1.14	1.18	.37
Sixth	1.54	1.47	1.63	1.55	....

The laboratory observations at Douglas, Mich., show that the number of molts of the codling moth may vary even under uniform conditions. The great majority, however, have six larval instars, a few only five, and very exceptionally seven instars.

Head measurements, when used in a series of consecutive tests, will bring out the number of molts of the larvæ, but this method can not be relied upon in determining the instars of any given larva, owing to the variability in size. The final averages as shown in Table LXXXI bring out the average widths of the head of the codling moth larva in its successive instars and also the rate of increase of each molt.

In 1881 Edwards[1] pointed out that the number of molts depends largely upon climatic conditions, these molts being more frequent in warm climates where the growth is rapid than in cold climates where the growth is retarded. The present records on the number of molts of the codling moth in Michigan and in the Ozarks corroborate Edwards's statement. Jenne found seven instars in the South, while in the North the writer found six instars.

CANNIBALISM AMONG LARVÆ OF THE CODLING MOTH.

In confinement, when a large number of mature codling moth larvæ are kept together, it sometimes happens that certain larvæ will attack and kill weaker ones and later devour them. After such a feast the cannibal larva assumes a dull, turbid color and can be readily recognized from the rest. It is evident that cannibalism among the larvæ also takes place under normal conditions. It has frequently been noted that a number of newly hatched larvæ have entered the same apple, but only a single or a few larvæ matured in the same fruit. Occasionally larvæ have been collected from bands which had the characteristic appearance of cannibal larvæ.

CODLING MOTH LARVÆ REMAINING TWO SEASONS IN THE LARVAL STAGE.

An unusual observation on the duration of the larval stage of the codling moth was made in 1909 and 1910 by Mr. R. W. Braucher at Douglas, Mich. In the fall of 1908 a number of larvæ were collected for rearing purposes and for studies to be made the following spring. Two of the larvæ failed to transform in 1909 and both were alive the following spring, 1910. On April 30 one larva had pupated; the other larva died June 24. The pupa, too, finally failed and was found dead July 18. Considering that the larva left the fruit about September 1, 1908, or possibly much earlier, we find that one of the insects

[1] Psyche, vol. 3, p. 159.

remained 20 months in the larval stage without taking food or water and that the other specimen remained 23 months in the cocoon as larva and pupa. The two larvæ had made their cocoons in a large glass vial. They came under the writer's observation in 1910.

The ability of an insect to remain dormant for a whole season and to transform subsequently the third season may possibly occur more frequently than has been actually observed. Such an adaptation would be of particular advantage to the species in surviving adverse seasons.

CODLING MOTH LARVÆ FEEDING ON APPLE FOLIAGE.

To test the feeding habits of the codling moth larvæ on apple foliage three branches from which the fruit had been removed were bagged and on each 10 newly hatched larvæ were placed June 10. When examined July 20 it was found that in all three bags feeding had taken place, and particularly had the tender growths at the tips of the branches been eaten. In one of the bags, at the place where the same had been tied around the branch, one half-grown dead codling-moth larva was found in a cocoon. In one of the other bags one dead pupa was found, which was hardly two-thirds the average size. In the third bag no insect was found, though there was evidence of feeding. It may thus be suspected that in cases of total crop failures the insect can subsist on foliage in sufficient numbers for the perpetuation of the species.

SUMMARY.

The present account of the life history of the codling moth in Michigan is based upon a series of studies made in 1909, 1910, and 1911.

In the course of a year the codling moth in Michigan produces one full brood and a partial second.

In the field the earliest moths of the spring brood commence to appear from 5 to 10 days after the apple blossoms drop, and the earliest larvæ of the first brood hatch from 3 to 4 weeks after the petals drop. The earliest larvæ of the second brood hatch from 10 to 11 weeks after the petals drop. During exceptionally warm and forward seasons the second-brood larvæ may appear considerably earlier, and were, in 1911, observed 8 weeks after the petals dropped. This record, however, should be considered very exceptional.

The time of appearance and the periods of occurrence of the different stages of the codling moth are shown in figure 11, which, with the exception of the spring pupal stage, closely represents the seasonal progress under average conditions. Figure 20 similarly shows this progress in the development of the insect under prevailing warm and exceptionally forward seasonal conditions.

Egg deposition commenced in the cages from 3 to 9 days after the emergence of the moths, and most of the eggs were laid within 5 days after egg deposition commenced. In one instance eggs were laid 23 days after the emergence of the moth, but as a rule the great majority of the eggs were laid within 8 days of the emergence.

The number of eggs per female varied considerably in the cages—on an average, 57 eggs per female were obtained. A single female deposited 161 eggs. Under normal conditions in the field the average number of eggs is unquestionably higher and probably approaches 80 to 90 eggs per female.

The average length of life of the moths was found to be 9 days for the males and 11 days for the females. Instances occurred when one male lived 32 days and a female lived 37 days.

The length of the incubation period of the eggs varied greatly under different temperature conditions. For the first brood the average length was 7 days and for the second brood 8 days. The range of variation extended from 4 to 16 days.

The effect of the temperature upon the length of the incubation period is shown by a plotted curve in figure 15.

The length of the feeding period of the larvæ of the first brood varied from 17 to 45 days and averaged 25 days for the "transforming" larvæ and 28 days for the "wintering" larvæ. Still larger variation in the length of feeding was observed in the second brood, ranging from 20 to 84 days and averaging 36 days.

On an average the larvæ spun their cocoons and pupated in 7 days. This period varied, however, from 3 to 18 days.

The pupal stage varied greatly under different temperature conditions, as is illustrated in figure 13. The average length of the pupal stage was 18 days and ranged from 1 week to 2 months.

The length of the first generation, from the time of the appearance of the eggs to the time of emergence of the moths that resulted from the same, averaged 51 days in 1910. During 1911 the duration of the life cycle varied from 29 to 87 days and averaged 50 days.

The relative abundance of first-brood and second-brood larvæ varied from year to year. In 1909 the second-brood larvæ surpassed the first brood in numbers and constituted 57 per cent of the larvæ for the season. During 1910, owing to the wide-felt scarcity of apples, the second brood only reached one-third the number of the first brood. During 1911 the second brood almost approached the first brood in abundance.

Of the first-brood larvæ only a portion transformed the same season, while the other portion passed the winter in the larval stage. During the three years of observation the ratio between transforming and wintering larvæ of the first brood varied from 30: 70 per cent to

51:49 per cent, respectively, and averaged 36 per cent transforming larvæ and 64 per cent wintering larvæ.

The larvæ of either brood shed the skin (molted) five times, and had thus six "instars." A limited number of larvæ molted only four times.

A hymenopterous fly, *Ascogaster carpocapsæ* Vier., was found to parasitize from 6 to 7 per cent of the larvæ of the codling moth.

Hibernating codling-moth larvæ succumb extensively to the cold during the winter. From 25 to 35 per cent were found to be killed.

From the foregoing records of the life history of the codling moth and from the variability of results obtained, it is evident that reliable data can only be obtained from a large number of observations.

From the point of view of mechanical control of the codling moth the most important observations of the habits of the insect relate to the time of emergence of the moths in the separate broods. Such observations should preferably be made from carefully conducted band records. It is essential that the collecting of larvæ from the banded trees should commence sufficiently early in the season so that the first-appearing larva may be secured. It is also of importance to make the collections at regular and frequent intervals (three days) and for the entire season. Apple trees of late varieties should be selected whenever available.

On applying the results of this investigation to the present methods of controlling the codling moth in Michigan it will be found that the poison-spray applications should be most effective when applied at the following periods:

First.—Shortly after the petals drop, to fill the open calyx cup and thus destroy the larvæ which hatch later. It is the habit of most of the first-brood larvæ to penetrate the apple through the calyx end.

Second.—From three to four weeks after the petals have dropped, when the first-brood larvæ commence to hatch.

Third.—Ten weeks after the petals have dropped, when under normal seasons the first larvæ of the second brood commence to appear. During advanced seasons the above period may be shortened to nine weeks and only very exceptionally to eight weeks, as noted in 1911.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 115, Part II.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

(SECOND REPORT.)

BY

A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations,

AND

E. W. SCOTT,

Entomological Assistant.

ISSUED NOVEMBER 4, 1912.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1912.

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J. F. Zimmer, W. S. Abbott, W. H. Sill, *entomological assistants, employed in enforcement of insecticide act, 1910.*

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THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

(Second Report.)

By

A. L. Quaintance, *In Charge of Deciduous Fruit Insect Investigations,*

and

E. W. Scott, *Entomological Assistant.*

INTRODUCTION.

The present paper constitutes the second report on the "one-spray" method in the control of the codling moth in comparison with the usual demonstration treatment of from three to five applications according to locality. The previous report on this subject will be found in Bulletin 80, Part VII (Revised), pages 113 to 146 (1911) of the Bureau of Entomology. The experiments herewith reported are in continuation of those detailed in the publication cited, and have been done in connection with other experimental work at several of the bureau's field stations. In addition to the insect questions investigated in a given locality, attention has also been given to the control of certain diseases of the apple, this latter in cooperation with Mr. W. M. Scott, then of the Bureau of Plant Industry of this department. These tests have been made, as in the work previously reported, in widely separated States, representing a considerable range in climatic and other conditions, and were carried out as closely as possible according to a uniform plan, for the most part by different members of the force engaged in Deciduous Fruit Insect Investigations. The experiments in Virginia in 1910 were carried out by Messrs. J. W. Roberts and Leslie Pierce of the Bureau of Plant Industry and Messrs J. F. Zimmer and J. B. Gill of the Bureau of Entomology. The work in Michigan during 1911 was under the immediate direction of Mr. E. W. Scott, and in Delaware was done by Messrs. W. B. Wood and F. L. Simanton of the Bureau of Entomology and Mr. W. B. Middleton of the Bureau of Plant Industry. In Kansas, in 1911, the work was carried out by Mr. J. B. Gill of the Bureau of Entomology and Mr. Leslie Pierce of the Bureau of Plant Industry.

Since the appearance of the first report of the Bureau of Entomology on the one-spray method, additional information on the sub-

ject has been published by other workers, notably by Prof. W. E. Rumsey, in West Virginia Experiment Station Bulletin 127, and by Dr. E. P. Felt, in Circular 40 of the New York State Department of Agriculture and in the Journal of Economic Entomology for 1911 and for 1912. The information now available seems to warrant the conclusions given in the present paper.

EXPERIMENTS IN VIRGINIA.

The experiments in Virginia were carried out during the season of 1910 in the orchard of Mr. W. F. Gilkeson near Fishersville. The entire orchard consists of 30 acres, but only about three-fourths of this was used for the experiments, the remainder being sprayed by the owner. The experimental part comprised three plats, as shown

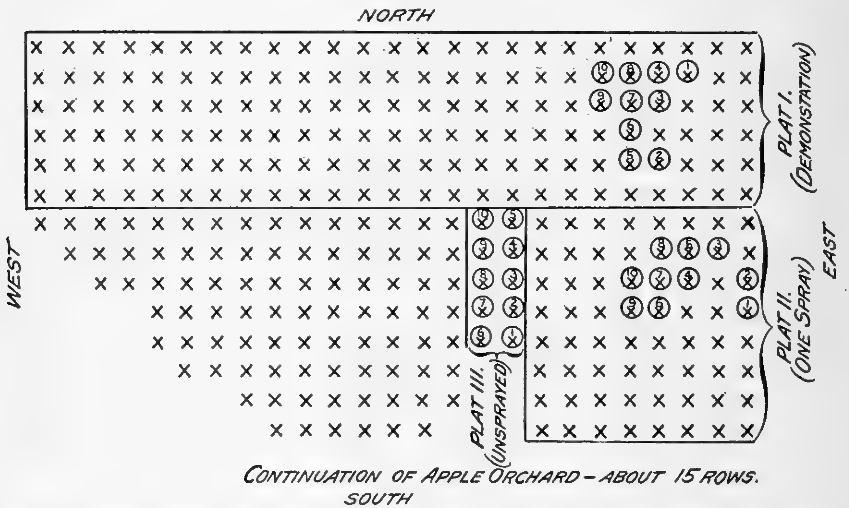

FIG. 23.—Diagram showing arrangement of plats and trees in the W. F. Gilkeson orchard, near Fishersville, Va. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Variety, York Imperial. (Original.)

in the accompanying diagram (fig. 23). The trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. The orchard is on a hillside gradually sloping to the southeast. It had a good cover crop of June grass and clover and was kept clean of dead limbs and rubbish, and the trees are headed rather low, thus facilitating spraying. The principal variety is York Imperial. There are a few Early Harvest trees scattered throughout the orchard, but none of these latter was included among the count trees. Plat I included 150 trees, Plat II 64 trees, and Plat III (the unsprayed plat) 10 trees, this last plat being in the center of the orchard. The treatments which the respective plats received are shown in Table I.

TABLE I.—*Treatments and dates of applications for the codling moth and the plum curculio. One-spray method. Fishersville, Va., 1910.*

Dates of application.	Plat I.	Plat II. (One-spray method.)	Plat III. (Unsprayed.)
First application, Apr. 16–18 (as soon as petals fell).	Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Pressure, 200 pounds.	Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Bordeaux nozzles. Pressure, 200–225 pounds.	Unsprayed.
Second application, May 16	do	Commercial lime-sulphur only (1½–50). Not drenched. No arsenical.	Do.
Third application, June 22	do	do	Do.

Plat I was sprayed thoroughly three times but was not drenched. Commercial lime-sulphur wash and arsenate of lead were used for each applicatoin. Plat II (one-spray method) was thoroughly drenched, Bordeaux nozzles and high pressure being used. This plat received one application of arsenate of lead and commercial lime-sulphur and two subsequent applications of commercial lime-sulphur only.

THE CODLING MOTH.

In Table II is shown the total wormy fruit and fruit free from injury by the codling moth for the entire season for the eight count trees of each plat, the number of the trees in the figure agreeing with those in the table.

TABLE II.—*Number of sound and wormy apples for each tree from demonstration, one-spray and unsprayed plats. Fisherville, Va., 1910.*

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Tree 9.	Tree 10.	Total for plat.	Total per cent of sound fruit.
PLAT I. LIME-SULPHUR DEMONSTRATION.												
Wormy	141	29	47	80	35	27	31	72	22	12	496	......
Sound	21,324	9,131	9,221	9,445	8,749	6,560	6,373	6,980	5,622	2,566	85,971	......
Total	21,465	9,160	9,268	9,525	8,784	6,587	6,404	7,052	5,644	2,578	86,467	......
Per cent sound	99.34	99.68	99.49	99.16	99.60	99.59	99.51	98.97	99.61	99.53	......	99.42
PLAT II. ONE-SPRAY METHOD.												
Wormy	82	88	63	63	6	29	33	77	41	23	505	......
Sound	7,282	6,543	8,044	7,539	2,023	3,372	3,777	5,873	3,065	3,127	50,645	......
Total	7,364	6,631	8,107	7,602	2,029	3,401	3,810	5,950	3,106	3,150	51,150	......
Per cent sound	98.88	98.67	99.22	99.17	99.70	99.14	99.13	98.70	99.68	99.27	......	99.01
PLAT III. UNSPRAYED.												
Wormy	781	423	487	480	355	296	812	188	421	776	5,019	......
Sound	5,159	1,908	3,067	2,935	1,874	1,329	4,413	1,168	2,285	3,227	27,365	......
Total	5,940	2,331	3,554	3,415	2,229	1,625	5,225	1,356	2,706	4,003	32,384	......
Per cent sound	86.85	81.84	86.29	85.94	84.07	81.78	84.45	86.13	84.44	80.61	......	84.50

Plat I, which received all three applications of arsenate of lead, gave 99.42 per cent fruit free from codling-moth injury, the percentage for individual trees ranging from 98.97 to 99.68. The total number of apples counted from this plat was 86,467. Plat II received the one-spray treatment and shows a total of 99.01 per cent of fruit free from codling-moth injury, the percentages for individual trees ranging from 98.67 to 99.70, and the total number of apples examined being 51,150. This shows a difference of only 0.41 per cent in favor of the demonstration. Plat III, the unsprayed plat, shows 84.50 per cent fruit free from codling-moth injury, the total number of apples examined being 32,384. This shows a gain in sound fruit by the demonstration treatment of 14.92 per cent, and by the one-spray method a gain of 14.51. As will be noted, the percentages of sound fruit from the check trees is rather high. This is probably very largely due to the fact that these were located in the center of the orchard, all the surrounding trees being sprayed.

In Table III are shown the places of entrance into the apple of the total larvæ for the season for each tree of each plat, and also the percentage, by plats, entering the fruit at the calyx, side, and stem.

There was a total of 496 larvæ on the demonstration plat, as against 505 larvæ on the one-spray plat, a difference of only 9 larvæ in favor of the demonstration plat. On the unsprayed plat there was a total of 5,019 larvæ. Comparing the percentages of larvæ entering at the calyx end of the apple on the different plats it will be noted that the demonstration plat shows 33.06 per cent entering at the calyx end as compared with 13.46 per cent on the one-spray plat. The unsprayed plat shows 63.86 per cent of larvæ entering at this point, which may be taken to indicate the normal behavior of the larvæ.

Table IV shows the comparative efficiency of the demonstration and one-spray treatments in preventing infestation at calyx, side, and stem.

By comparing the figures for the different plats it will be seen that the one-spray treatment was more effective than the demonstration in preventing entrance at the calyx, and less effective in preventing entrance at the side and stem. The demonstration treatment saved a total of only 0.41 per cent more of the crop than the one-spray method, most of this saving being due to prevention of side entrances.

TABLE III.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fishersville, Va., 1910.*

PLAT I. LIME-SULPHUR DEMONSTRATION.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Tree 9.	Tree 10.	Total for plats.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
	Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined.												
First and second broods:													
Calyx	49	6	14	25	5	10	16	32	4	3	164	33.06	....
Side	60	20	26	40	22	12	11	14	12	9	226	45.57	....
Stem	32	3	7	15	8	5	4	26	6	0	106	21.37	....
Total	141	29	47	80	35	27	31	72	22	12	496	100.00	496

PLAT II. ONE-SPRAY METHOD.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Tree 9.	Tree 10.	Total for plats.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:													
Calyx	8	11	6	7	1	4	12	11	4	4	68	13.46	....
Side	45	49	42	30	4	14	17	40	26	13	280	55.45	....
Stem	29	28	15	26	1	11	4	26	11	6	157	31.09	....
Total	82	88	63	63	6	29	33	77	41	23	505	100.00	505

PLAT III. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Tree 9.	Tree 10.	Total for plats.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:													
Calyx	487	252	297	296	244	196	561	111	251	510	3,205	63.86	....
Side	132	78	88	100	60	58	93	43	62	105	819	16.32	....
Stem	162	93	102	84	51	42	158	34	108	161	995	19.82	....
Total	781	423	487	480	355	296	812	188	421	776	5,019	100.00	5,019

TABLE IV.—*Efficiency of the demonstration and one-spray treatments as shown by the percentage of wormy apples. Fishersville, Va., 1910.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
I. Demonstration	0.19	0.26	0.12	0.57	496	86,467
II. One spray	.13	.54	.31	.98	505	51,150
III. Unsprayed	9.89	2.53	3.07	15.49	5,019	32,384

THE PLUM CURCULIO.

Table V shows the effect of the treatments in the W. F. Gilkeson orchard in controlling the plum curculio on the three plats. Egg and feeding punctures are combined in the table under "Number of punctures."

TABLE V.—*Injury by the plum curculio for entire season. Plats I, II, and III. Fishersville, Va., 1910.*

Number of punctured and sound apples, etc., per tree in each plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Tree 7.	Tree 8.	Tree 9.	Tree 10.	Total for plat.	Total per cent of of fruit free from injury.
PLAT I. LIME-SULPHUR DEMONSTRATION.												
Number punctures	1,333	677	618	747	864	757	835	819	369	210	7,229	....
Number fruit punctured	987	321	397	471	522	483	476	542	239	123	4,561	....
Number sound fruit	20,478	8,839	8,871	9,054	8,262	6,104	5,928	6,510	5,405	2,455	81,906	....
Number fruit	21,465	9,160	9,268	9,525	8,784	6,587	6,404	7,052	5,644	2,578	86,467	....
Per cent free from injury	95.40	96.49	95.71	95.05	94.05	92.66	92.56	92.31	95.76	95.22	....	94.72
PLAT II. ONE-SPRAY METHOD.												
Number punctures	855	1,025	563	744	113	271	231	314	149	223	4,488	....
Number fruit punctured	428	584	544	516	107	156	143	202	90	112	2,882	....
Number sound fruit	6,936	6,140	7,563	7,086	1,918	3,245	3,667	5,748	3,015	3,037	48,355	....
Number fruit	7,364	6,724	8,107	7,602	2,025	3,401	3,810	5,950	3,105	3,149	51,237	....
Per cent free from injury	94.20	91.31	93.28	93.21	94.71	95.41	96.24	96.60	97.10	96.44	....	94.37
PLAT III. UNSPRAYED.												
Number punctures	917	311	332	483	231	168	683	146	342	620	4,233	....
Number fruit punctured	673	246	297	344	165	128	463	81	283	434	3,114	....
Number sound fruit	5,267	2,085	3,257	3,071	2,064	1,497	4,762	1,275	2,423	3,569	29,270	....
Number fruit	5,940	2,331	3,554	3,415	2,229	1,625	5,225	1,356	2,706	4,003	32,384	....
Per cent free from injury	88.67	89.44	91.64	89.92	92.59	92.12	91.13	94.02	89.54	89.15	....	90.38

On the demonstration plat the percentage of fruit uninjured by the curculio was 94.72, and on the one-spray plat 94.37, which shows only 0.35 per cent in favor of the demonstration plat. The unsprayed plat shows 90.38 per cent free from curculio injury. As has been noted, the check trees were in the center of the orchard and surrounded by sprayed trees, which no doubt accounts largely for the high percentage of sound fruit on the check plat.

EXPERIMENTS IN MICHIGAN.

The experiments in Michigan during the season of 1911 were carried out in Mr. Edward Hutchins's orchard near Fennville, Mich. The entire orchard, consisting of 205 trees, was used for the experimental and demonstration spraying, the experimental part being located in the western portion of the orchard where the principal varieties are Baldwin and Rhode Island Greening. The plats were laid off across these varieties in order to have both represented in each plat. (See fig. 24.) The east side of the orchard is composed of a general mixture of many varieties. Trees of each plat from which the fruit was

counted throughout the season for records are designated by the same numbers which these trees bear in the tables. The orchard is almost level, sloping slightly toward the west. It was kept clean, cultivated throughout the summer, and sown to oats in the fall for cover crop. The trees are 30 years old and medium to large in size. Plat I included 18 trees; Plat II, 17 trees; Plat III, 19 trees; Plat IV, 12 trees; Plat V (the unsprayed plat), 21 trees, this last plat extending across the orchard near the center. The treatments given and dates of application are shown in Table VI.

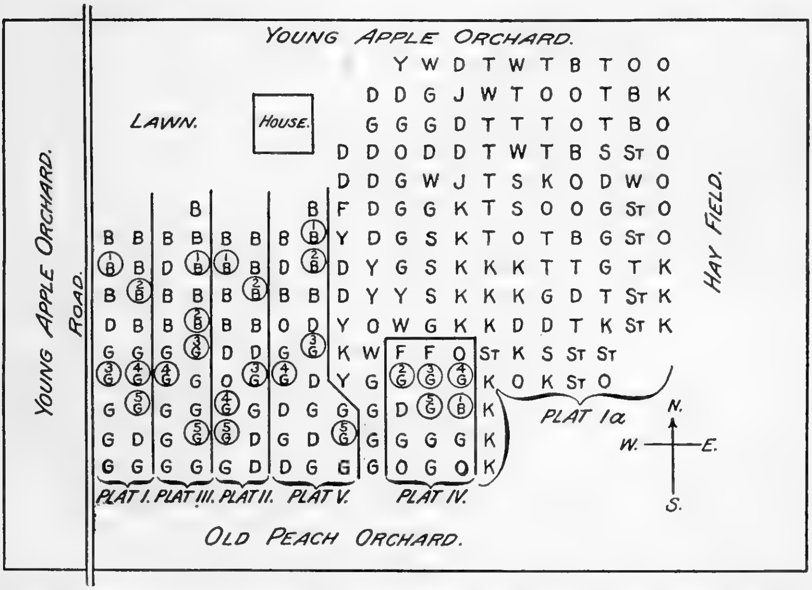

FIG. 24.—Diagram showing arrangement of plats and trees in the Edward Hutchins orchard, near Fennville, Mich. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Varieties: *B*, Baldwin; *G*, Rhode Island Greening (counts were made from these first two varieties only); *D*, Dutchess; *Y*, Yellow Transparent; *K*, King; *F*, Fall Pippin; *St*, Stark; *S*, Sweet Greening; *W*, Wagner; *T*, Tolman Sweet; *J*, Jersey Sweet. (Original.)

TABLE VI.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method, etc. Fennville, Mich., 1911.*

Dates of application.	Plat I.	Plat II.	Plat III. (One-spray method.)
First application, May 12 (after cluster buds open.)	Scab treatment. Commercial lime-sulphur (1½–50) alone.	Scab treatment. Home-boiled lime-sulphur (4S–2L–50) alone.	Scab treatment. Commercial lime-sulphur (1½–50) alone.
Second application, May 25 (as soon as petals dropped).	Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Pressure, 125 pounds.	Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons home-boiled lime-sulphur (4S–2L–50). Pressure, 125 pounds.	Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Bordeaux nozzles. Pressure, 150–175 pounds.
Third application, June 14.	.....do.....	.....do.....	Commercial lime-sulphur only (1½–50). Not drenched.
Fourth application, July 25.	.....do.....	.....do.....	Do.

TABLE VI.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method, etc. Fennville, Mich., 1911*—Continued.

Dates of application.	Plat IV.	Plat V. (Unsprayed.)
First application, May 12 (after cluster buds open).	Scab treatment. Bordeaux (4-4-50) alone......	Unsprayed.)
Second application, May 25 (as soon as petals dropped).	Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons Bordeaux (4-4-50). Pressure, 125 pounds.	Do.
Third application, June 14............	.....do..........	Do.
Fourth application, July 25............	.....do..........	Do.

All of the sprayed plats received an early application when the cluster buds opened for control of scab. No arsenate of lead was used with this application. Plats I, II, and IV received three subsequent treatments in which arsenate of lead was used with each treatment at the rate of 2 pounds to 50 gallons, the only difference in treatments of these three plats being that on Plat I the lead was used with commercial lime-sulphur, on Plat II with home-boiled lime-sulphur, and on Plat IV with Bordeaux. Mist or Vermorel nozzles were used for spraying these plats and a pressure of about 125 pounds was carried. The trees were given a thorough spraying. Plat III, the one-spray plat, was thoroughly drenched during the second application, the only application in which arsenate of lead was used on this plat. A pressure of about 150 pounds was carried, and Bordeaux nozzles were used, giving a coarse, driving spray. This plat received for this application an average of 16 gallons per tree as against 14 gallons per tree for the same application on the other plats.

The dropped fruit was picked up from under the count trees about every 10 days throughout the season and carefully examined as to codling-moth and curculio injury. The fruit picked from the tree in the fall was examined in the same way, and the results presented include all the dropped fruit and the fruit picked from the tree.

THE CODLING MOTH.

In Table VII are shown the results of treatment of all the plats as to injury from the codling moth, these results being obtained from three Rhode Island Greening trees of each plat. The numbers of the trees in the table agree with those in the diagram of the orchard (fig. 24).

TABLE VII.—*Number of sound and wormy apples for each tree from commercial lime-sulphur, home-boiled sulphur, Bordeaux, one-spray method, and unsprayed plats. Fennville, Mich., 1911.*

PLAT I. COMMERCIAL LIME-SULPHUR DEMONSTRATION.

Condition of fruit.	Tree 3.	Tree 4.	Tree 5.	Total for plat.	Total per cent of sound fruit.
Wormy	154	85	32	271	
Sound	1,914	946	694	3,554	
Total	2,068	1,031	726	3,825	
Per cent sound	92.55	91.75	95.59		92.91
PLAT II. HOME-BOILED LIME-SULPHUR DEMONSTRATION.					
Wormy	84	76	88	248	
Sound	1,899	2,702	1,862	6,463	
Total	1,983	2,778	1,950	6,711	
Per cent sound	95.76	97.26	95.48		96.30
PLAT III. ONE-SPRAY METHOD.					
Wormy	50	510	123	683	
Sound	606	2,494	1,492	4,592	
Total	656	3,004	1,615	5,275	
Per cent sound	92.37	83.02	92.38		87.05
PLAT IV. BORDEAUX-MIXTURE DEMONSTRATION.					
Wormy	12	146	23	181	
Sound	684	2,157	1,119	3,960	
Total	696	2,303	1,142	4,141	
Per cent sound	98.27	93.66	97.98		95.62
PLAT V. UNSPRAYED.					
Wormy	766	1,013	1,302	3,081	
Sound	901	1,468	1,062	3,437	
Total	1,667	2,481	2,370	6,518	
Per cent sound	54.04	59.16	44.81		52.73

As will be seen from the foregoing table, there were counted from Plats I, II, III, IV, and V, respectively, 3,825, 6,711, 5,275, 4,141, and 6,518 apples, a total for all plats of 26,470. (In giving the results from all of the other one-spray experiments presented in this paper the one-spray plat is compared with the commercial lime-sulphur demonstration; therefore, for sake of uniformity, the same comparison is made in this experiment.) Plat I, which received the commercial lime-sulphur treatment, shows for the individual trees a range in percentage of fruit free from the codling moth of 91.75 to

95.59, with a total for all trees of 92.91, as against a total of 87.05 per cent free from this insect in Plat III, the one-spray plat, a difference in favor of Plat I of 5.86 per cent. The range for individual trees in Plat III was 83.02 to 92.38. Plat V, the unsprayed plat, shows a total percentage of 52.73 of fruit free from the codling moth, the range being from 44.81 to 59.16. There is thus a gain over the unsprayed fruit in sound fruit by the demonstration treatment of 40.18 per cent and by the one-spray method a gain of 34.32 per cent of sound fruit. (See Pl. IV, figs. 1, 2, 3.)

Plat II, which received the home-boiled lime-sulphur demonstration treatment, shows a total percentage of fruit free from injury of 96.30, and Plat IV, the Bordeaux demonstration plat, shows 95.62 per cent of fruit free from injury.

In Table VIII are shown the places of entrance of the fruit for each tree of each plat for the total larvæ throughout the season.

TABLE VIII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fennville, Mich., 1911.*

PLAT I. COMMERCIAL LIME-SULPHUR DEMONSTRATION.

Total number of larvæ and place of entrance of fruit for each tree; first and second broods combined.				Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
Place of entrance.	Tree 3.	Tree 4.	Tree 5.			
First and second broods:						
Calyx	12	21	8	41	13.62	
Side	164	64	26	254	84.39	
Stem	2	3	1	6	1.99	
Total	178	88	35	301	100.00	301

PLAT II. HOME-BOILED LIME-SULPHUR DEMONSTRATION.

First and second broods:						
Calyx	6	7	6	19	6.15	
Side	102	79	104	285	92.23	
Stem	2	2	1	5	1.62	
Total	110	88	111	309	100.00	309

PLAT III. ONE-SPRAY METHOD.

First and second broods:						
Calyx	4	54	7	65	6.65	
Side	65	661	153	879	89.97	
Stem	4	24	5	33	3.38	
Total	73	739	165	977	100.00	977

PLAT IV. BORDEAUX-MIXTURE DEMONSTRATION.

First and second broods:						
Calyx	3	47	5	55	27.64	
Side	8	109	19	136	68.34	
Stem	1	5	2	8	4.02	
Total	12	161	26	199	100.00	199

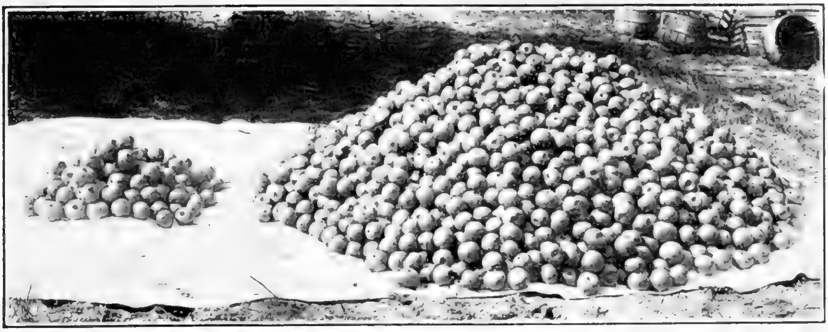

FIG. 1.—PICKED APPLES FROM THREE TREES OF PLAT I (DEMONSTRATION) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL.)

FIG. 2.—PICKED APPLES FROM THREE TREES OF PLAT III (ONE-SPRAY) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL.)

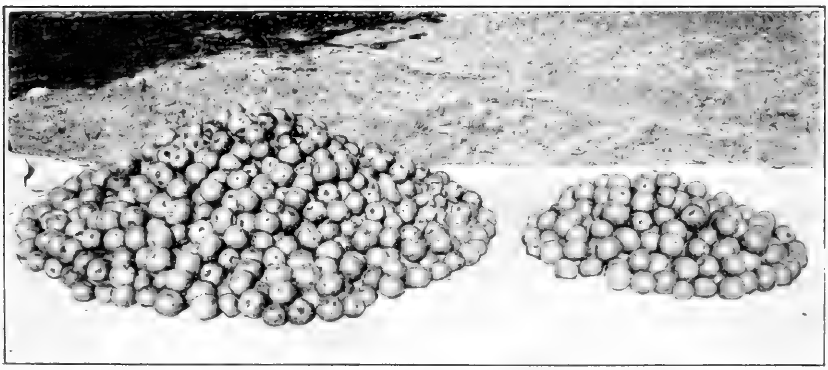

FIG. 3.—PICKED APPLES FROM THREE TREES OF PLAT V (UNSPRAYED) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL

TABLE VIII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fennville, Mich., 1911*—Continued.

PLAT V. UNSPRAYED.

Total number of larvæ and place of entrance of fruit for each tree; first and second broods combined.				Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
Place of entrance.	Tree 3.	Tree 4.	Tree 5.			
First and second broods:						
Calyx	577	856	1,022	2,455	54.21	....
Side	553	574	593	1,720	37.98	....
Stem	99	139	116	354	7.81	....
Total	1,229	1,569	1,731	4,529	100.00	4,529

As shown in the above table, the total number of larvæ on Plats I, III, and V were 301, 977, and 4,529, respectively. The unsprayed plat (Plat V) may be taken to indicate the normal behavior of the larvæ and shows that 54.21 per cent of the total larvæ of both broods entered the calyx end of the apples. In case of the sprayed plats, as would be expected, the proportion entering at the calyx is greatly reduced, and there is a corresponding increase in the proportion entering the fruit at the side and stem. The demonstration plat shows 13.62 per cent of total larvæ entering at the calyx end as compared with 6.65 per cent in the one-spray plat. Comparing the percentage of larvæ entering at the stem end of the apple it will be noted that this percentage on Plat I is 1.99, as compared with 3.38 per cent on the one-spray plat. It would be expected that this difference would be due to the protection of the stem end of the apple by the later applications of poison on the demonstration plat, and this is probably a correct conclusion. However, by referring to the foregoing table it will be seen that in the case of Plat IV, the Bordeaux-demonstration plat, 4.02 per cent of larvæ entered at the stem end.

The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table IX.

TABLE IX.—*Efficiency of the demonstration and one-spray treatments as shown by the percentage of wormy apples. Fennville, Mich., 1911.*

Plat No.	Percentage of wormy apples.[1]				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
I. Demonstration	0.96	5.98	0.14	7.08	271	3,825
III. One-spray	.86	11.64	.44	12.94	683	5,275
V. Unsprayed	25.62	17.95	3.69	47.26	3,081	6,518

[1] Each entrance was counted in determining the percentages for calyx, side, and stem, so that the sum of these percentages exceeds the total percentages of wormy fruit.

Here, as in the foregoing experiment, the one-spray treatment was more efficient than the demonstration treatment in preventing entrance at the calyx, the difference being 0.10 per cent in favor of the one-spray treatment. However, the one-spray treatment afforded only about one-half as much protection as the demonstration treatment against side worminess. In comparing the total efficiency of the two treatments it will be seen that there was a saving of 40.18 per cent of the crop in Plat I and of 34.32 per cent in Plat III.

EXPERIMENTS IN DELAWARE.

The experiments in Delaware in 1911 were carried out in the orchard of F. C. Bancroft, near Camden, Del. The part of the orchard used for this experiment was a block of about 600 trees somewhat isolated from the rest of the apple orchard. On the north side was a peach orchard, on the east and south a pear orchard, and on the west a cornfield. The orchard was almost level, having just enough slope to drain well. It was well tilled throughout the season. The main variety was Stayman Winesap, with Missouri Pippin used as the principal filler. The trees were 16 years old and were rather large for their age. The plats were laid out diagonally across the orchard, as shown in the accompanying diagram (fig. 25). Trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. Plat II includes 60 trees; Plat III, 52 trees; Plat VII, 39 trees, and Plat VIII, 25 trees. The treatments to which the respective plats were subjected are shown in Table X.

TABLE X.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method. Camden, Del., 1911.*

Dates of application.	Plat II. (Demonstration.) Commercial lime-sulphur and arsenate of lead.	Plat VII. (One-spray method.) Commercial lime-sulphur and arsenate of lead.	Plat VIII. (Unsprayed.)
First application, Apr. 27 (before blossoms opened).	Scab treatment. Mist spray. Commercial lime-sulphur (1¼–50) plus 2 pounds of arsenate of lead. Pressure, 140 pounds.	Scab treatment. Mist spray. Commercial lime-sulphur alone (1½–50). Pressure, 140 pounds.	Unsprayed.
Second application, May 13 and 15 (after petals dropped).	Not drenched. Mist nozzles used. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur. Pressure, 140 pounds.	Drenched with arsenate of lead, 2 pounds to 50 gallons of commercial lime-sulphur (1¼–50). Coarse spray. Bordeaux nozzles. Pressure, 140-150 pounds.	Do.
Third application, June 7...	.....do......................	Commercial lime-sulphur alone (1½–50). Not drenched.	Do.
Fourth application, July 10.	.....do......................	.....do......................	Do.

Both sprayed plats received four applications in all, the first before blooming, but after cluster buds had opened, to protect the fruit from apple scab. Plat II received arsenate of lead at the rate of 2 pounds to 50 gallons of lime-sulphur for each application. Plat VII, the one-spray plat, received the arsenate-of-lead treatment

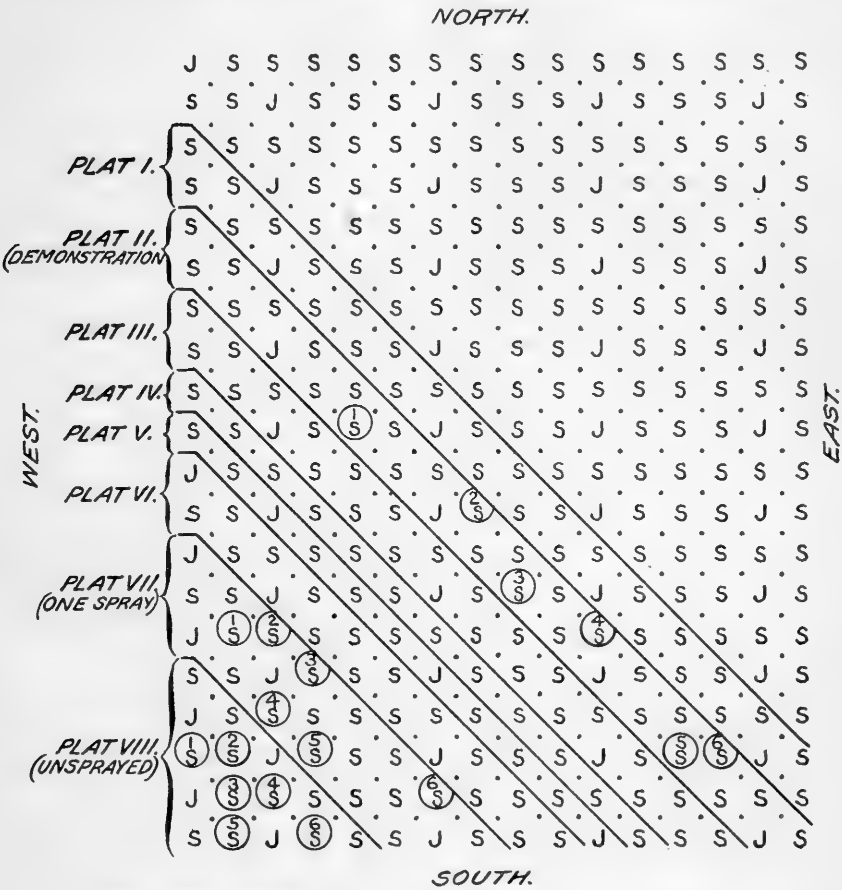

FIG. 25.—Diagram showing arrangement of plats and trees in the F. C. Bancroft orchard, near Camden, Del.: *S*, Stayman; *J*, Jonathan; (.), Mixed varieties used as fillers. Count trees are indicated by circles, the numbers agreeing with those in the tables. (Original.)

only for the second application, which was made immediately after the falling of the petals. Both plats were thoroughly sprayed but not drenched, except at the time of the second application, when the one-spray plat was drenched, for which purpose Bordeaux nozzles were used, the demonstration plat being sprayed as usual with mist nozzles. Plat VIII was left unsprayed throughout.

THE CODLING MOTH.

In Table XI are shown results of treatments on Plats II and VII as compared with Plat VIII (the unsprayed plat) as to injury from the codling moth.

TABLE XI.—*Number of sound and wormy apples from each tree from demonstration, one-spray, and unsprayed plats. Camden, Del., 1911.*

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Total per cent of sound fruit.
PLAT II. LIME-SULPHUR DEMONSTRATION.								
Wormy	27	42	35	11	26	6	147	....
Sound	3,655	2,365	3,737	2,693	4,751	2,720	19,921	....
Total	3,682	2,407	3,772	2,704	4,777	2,726	20,068	....
Per cent sound	99.26	98.25	99.07	99.59	99.45	99.77	....	99.27
PLAT VII. ONE-SPRAY METHOD.								
Wormy	237	210	121	284	187	264	1,303	....
Sound	2,327	1,884	2,696	4,240	2,906	2,828	16,881	....
Total	2,564	2,094	2,817	4,524	3,093	3,092	18,184	....
Per cent sound	90.75	89.97	95.70	93.72	93.95	91.46	....	92.83
PLAT VIII. UNSPRAYED.								
Wormy	2,064	2,427	1,509	1,761	2,465	1,555	11,781	....
Sound	1,404	2,471	1,712	962	1,678	806	9,033	....
Total	3,468	4,898	3,221	2,723	4,143	2,361	20,814	....
Per cent sound	40.48	50.44	53.15	35.32	40.50	34.13	....	43.40

The total percentage of fruit free from codling-moth injury on the demonstration plat was 99.27, the range in percentage for individual trees being from 98.25 to 99.77. On the one-spray plat the total percentage free from this insect was 92.83, the range in percentage for the individual trees being from 89.97 to 95.70. The unsprayed plat shows only 43.40 per cent free from codling moth, with a range in percentage for individual trees of from 34.13 to 53.15. The demonstration plat shows an increase of sound fruit over the one-spray method of 6.44 per cent and over the unsprayed plat of 55.87 per cent. The one-spray plat shows an increase of sound fruit over the unsprayed plat of 49.43 per cent. The number of apples counted on the respective plats were 20,068, 18,184, and 20,814, giving a total of 59,066 for the three plats. By referring to the diagram of the orchard (fig. 25) it will be noted that the one-spray plat adjoined the unsprayed plat on the southwest side, which would tend to lower the efficiency of the spray owing to the migration of the moths from the unsprayed plat during the season.

Table XII gives the places of entrance of the fruit for each tree of each plat for the total larvæ of the two broods throughout the season.

TABLE XII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Camden, Del., 1911.*

PLAT II. LIME-SULPHUR DEMONSTRATION.

Place of entrance. (Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined.)	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	3	0	1	1	1	0	6	4.08	....
Side	22	39	31	6	22	5	125	85.03	....
Stem	2	3	3	4	3	1	16	10.89	....
Total	27	42	35	11	25	6	147	100.00	147

PLAT VII. ONE-SPRAY METHOD.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	14	14	6	10	8	13	65	4.99	....
Side	199	169	99	238	164	216	1,085	83.27	....
Stem	24	27	16	36	15	35	153	11.74	....
Total	237	210	121	284	187	264	1,303	100.00	1,303

PLAT VIII. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	1,324	686	970	1,142	1,472	999	6,593	55.96	....
Side	492	1,506	333	437	725	416	3,909	33.18	....
Stem	248	235	206	182	268	140	1,279	10.86	....
Total	2,064	2,427	1,509	1,761	2,465	1,555	11,781	100.00	11,781

On the demonstration plat there was a total of 147 larvæ; on the one-spray plat, 1,303 larvæ; and on the unsprayed plat, 11,781 larvæ. The notably greater number on the one-spray plat than on the demonstration plat is probably due to the former being next to the unsprayed plat, as above mentioned, from which moths no doubt migrated during the season.

A more ready comparison of the efficiency of the treatments of Plats II, VII, and VIII is given in Table XIII.

TABLE XIII.—*Efficiency of the demonstration and one-spray treatments for the codling moth as shown by the percentage of wormy apples. Camden, Del., 1911.*

Plat No.	Percentage of wormy apples. Calyx.	Side.	Stem.	Total.	Total number of wormy apples.	Total number of apples.
II. Demonstration	0.03	0.62	0.08	0.73	147	20,068
VII. One-spray	.36	5.96	.84	7.16	1,303	18,184
VIII. Unsprayed	31.67	18.78	6.15	56.60	11,781	20,814

It will be seen here that the one-spray method was nearly as effective as the demonstration in preventing calyx entrance, the difference in favor of the demonstration treatment being 0.33 per cent. The one-spray method in this case shows considerable protec-

tion against side worminess, but not so much as the demonstration, which shows an increase in side-entrance protection over the one-spray method of 5.34 per cent. The unsprayed plat shows 56.60 per cent of wormy fruit, so there is a total saving of 55.87 per cent of the crop by the demonstration treatment and 49.44 per cent by the one-spray treatment.

THE PLUM CURCULIO.

The plum curculio was considerably in evidence in the Bancroft orchard during 1911. The unsprayed plat (Table XIV) shows only 65.13 per cent free from curculio injury, while the demonstration plat shows 90.37 per cent free from this insect as against 85.69 per cent on the one-spray plat, the demonstration plat showing an increase in sound fruit over the one-spray plat of 4.68. The difference in favor of the demonstration plat was very probably influenced by the location of the one-spray plat as previously mentioned under the discussion of codling-moth injury.

TABLE XIV.—*Injury by the plum curculio for entire season. Plats II, VII, and VIII. Camden, Del., 1911.*

PLAT II. LIME-SULPHUR DEMONSTRATION.

Number of punctured and sound apples, etc., per tree.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Total per cent of fruit free from injury.
Number of punctures	641	265	440	281	821	374	2,822	....
Number of fruit punctured	384	169	337	204	576	261	1,931	....
Number of sound fruit	3,298	2,238	3,435	2,500	4,201	2,465	18,137	....
Number of fruit	3,682	2,407	3,772	2,704	4,777	2,726	20,068	....
Per cent free from injury	89.57	92.97	91.06	92.45	87.94	90.42	....	90.37

PLAT VII. ONE-SPRAY METHOD.

Number of punctures	710	349	614	784	548	779	3,784	....
Number of fruit punctured	458	252	417	606	444	425	2,602	....
Number of sound fruit	2,106	1,842	2,400	3,918	2,649	2,667	15,582	....
Number of fruit	2,564	2,094	2,817	4,524	3,093	3,092	18,184	....
Per cent free from injury	82.13	87.96	85.19	86.60	85.64	86.25	....	85.69

PLAT VIII. UNSPRAYED.

Number of punctures	1,322	2,602	1,700	1,599	2,964	1,898	12,085	....
Number of fruit punctured	902	1,599	1,114	889	1,712	1,041	7,257	....
Number of sound fruit	2,566	3,299	2,107	1,834	2,431	1,320	13,557	....
Number of fruit	3,468	4,898	3,221	2,723	4,143	2,361	20,814	....
Per cent free from injury	73.99	67.35	65.41	67.34	58.67	55.90	....	65.13

EXPERIMENTS IN KANSAS.

The experiments in Kansas during the season of 1911 were carried out in the Thomas Fruit Farm orchard near Wichita, Kans. This is a large orchard consisting of 76 acres, and is quite level. The soil is a sandy-loam type and was not well cultivated during the season.

The trees were 20 years old and well pruned. The orchard consists of blocks of several varieties, but the experimental plats were laid out in a block of Winesaps. The plats begin at the south-central side of

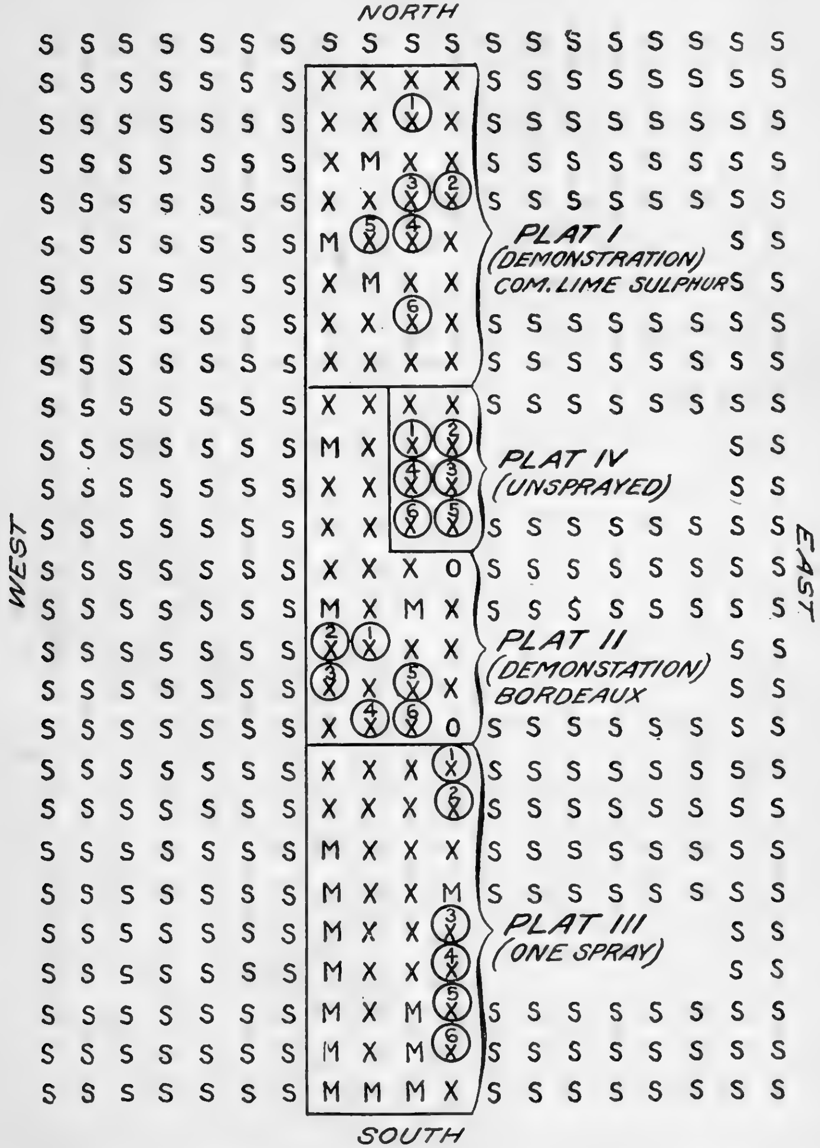

FIG. 26.—Diagram showing arrangement of plats and trees in the Thomas Fruit Farm orchard, near Wichita, Kans. Trees counted are indicated by circles, the numbers agreeing with the numbers in the tables. Trees marked *X*, Winesap variety. Those marked *S*, mixed varieties sprayed by owner. (Original.)

the orchard and extend north about halfway across. The unsprayed plat was located between Plats I and II, as is shown in the accompanying diagram (fig. 26). The trees surrounding the plats were

sprayed by the owner. Plat I includes 32 trees; Plat II, 24 trees; Plat III, 36 trees; and Plat IV, 8 trees. The treatments which the respective plats received are shown in Table XV.

TABLE XV.—*Treatments and dates of applications for the codling moth and the plum curculio. One-spray method. Wichita, Kans., 1911.*

Dates of application.	Plat I (demonstration). Commercial lime-sulphur and arsenate of lead.	Plat II (demonstration). Bordeaux and arsenate of lead.	Plat III (one-spray method). Commercial lime-sulphur and arsenate of lead.	Plat IV.
First application, Apr. 14 (before blossoms opened).	Not drenched. Blizzard nozzles. Coarse spray. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½-50). Pressure, 200 pounds.	Not drenched. Blizzard nozzles. Coarse spray. Arsenate of lead, 2 pounds to 50 gallons. Bordeaux (3-4-50). Pressure, 200 pounds.	Unsprayed	Unsprayed.
Second application, May 1 (after petals dropped).	do	do	Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½-50). Blizzard nozzles. Coarse spray. Pressure, 200-240 pounds.	Do.
Third application, May 19-22.	do	do	Unsprayed	Do.
Fourth application, July 1.	do	do	do	Do.

Plats I and II, the demonstration plats, received four applications in all, the first, before blooming but after the cluster buds opened, being applied for the cankerworm and apple scab. Plat I received arsenate of lead at the rate of 2 pounds to 50 gallons of commercial lime-sulphur. On Plat II Bordeaux was used instead of lime-sulphur; otherwise the treatments of the two plats were the same. Plat III, the one-spray plat, received only one application of arsenate of lead, 2 pounds to 50 gallons of commercial lime-sulphur. This was applied just after the petals fell. Plats I and II received 10 gallons of spray per tree each for the application at the time of the falling of the petals, while Plat III received 13 gallons per tree at that time. The coarse spray-nozzle was used on all plats for each application, but only the one-spray plat was drenched.

THE CODLING MOTH.

Table XVI shows the results of treatments of Plats I, II, and III, compared with the unsprayed plat (Plat IV) as to injury from the codling moth.

TABLE XVI.—*Number of sound and wormy apples for each tree from lime-sulphur, Bordeaux, one-spray, and unsprayed plats. Wichita, Kans., 1911.*

Condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Total per cent of sound fruit.
PLAT I. LIME-SULPHUR DEMONSTRATION.								
Wormy	111	194	157	177	127	204	970	
Sound	2,993	3,214	3,409	3,079	2,867	4,013	19,575	
Total	3,104	3,408	3,566	3,256	2,994	4,217	20,545	
Per cent sound	96.42	94.30	95.59	94.56	95.75	95.16		95.28
PLAT II. BORDEAUX DEMONSTRATION.								
Wormy	579	457	651	460	474	594	3,215	
Sound	3,139	2,324	3,389	3,267	3,475	2,525	18,119	
Total	3,718	2,781	4,040	3,727	3,949	3,119	21,334	
Per cent sound	84.42	83.56	83.88	87.65	87.99	80.95		84.93
PLAT III. ONE-SPRAY METHOD.								
Wormy	285	397	193	213	287	168	1,543	
Sound	2,168	3,552	630	602	721	529	8,202	
Total	2,453	3,949	823	815	1,008	697	9,745	
Per cent sound	88.38	89.94	76.54	73.86	71.52	75.89		84.16
PLAT IV. UNSPRAYED.								
Wormy	1,769	1,890	2,232	2,709	2,072	2,245	12,917	
Sound	1,114	1,166	960	1,000	704	645	5,589	
Total	2,883	3,056	3,192	3,709	2,776	2,890	18,506	
Per cent sound	38.64	38.15	30.07	26.96	25.36	22.31		30.20

By again comparing the one-spray method (Plat III) with the commercial lime-sulphur plat (Plat I), as has been done in the foregoing experiments, it will be noted that Plat I shows 95.28 per cent of fruit free from codling-moth injury as against 84.16 per cent free from this insect on Plat III. Plat IV, the unsprayed plat, shows only 30.20 per cent fruit free from codling-moth injury. Thus the commercial lime-sulphur demonstration plat shows an increase of sound fruit over the unsprayed plat of 65.08 per cent, while the one-spray plat shows an increase of 53.96 per cent over the unsprayed plat. The number of apples counted on the four plats, respectively, were 20,545, 21,334, 9,745, and 18,506, making a total of 70,130 for the four plats. One point in favor of the demonstration plat is that

there were over twice as many apples on the count trees, which would tend to decrease the total percentage of wormy fruit. However, as will be noted later, there were 573 more codling-moth larvæ on the one-spray plat than on the lime-sulphur demonstration plat.

The Bordeaux demonstration plat (No. II) did not give as good results as the lime-sulphur demonstration plat, the percentage of fruit free from codling-moth injury being 84.93, practically the same as on the one-spray plat. The notable difference between the two demonstration plats in percentage of sound fruit may be due to its location relative to the unsprayed plat or to some other local condition.

Table XVII shows the places of entrance of fruit by total larvæ for each tree of each plat.

TABLE XVII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Wichita, Kans, 1911.*

PLAT I. LIME-SULPHUR DEMONSTRATION.

Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined.							Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.			
First and second broods:									
Calyx	19	13	7	11	6	9	65	6.70	
Side	92	174	144	149	112	174	845	87.11	
Stem	0	7	6	17	9	21	60	6.19	
Total	111	194	157	177	127	204	970	100.00	970

PLAT II. BORDEAUX DEMONSTRATION.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	28	19	27	17	35	26	152	4.73	
Side	496	354	535	394	373	502	2,654	82.55	
Stem	55	84	89	49	66	66	409	12.72	
Total	579	457	651	460	474	594	3,215	100.00	3,215

PLAT III. ONE-SPRAY METHOD.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	23	32	14	18	24	20	131	8.49	
Side	236	323	151	172	239	134	1,255	81.34	
Stem	26	42	28	23	24	14	157	10.17	
Total	285	397	193	213	287	168	1,543	100.00	1,543

PLAT IV. UNSPRAYED.

Place of entrance.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Tree 6.	Total for plat.	Percentage of larvæ entering at calyx, side, and stem.	Total number of larvæ.
First and second broods:									
Calyx	1,039	1,107	1,338	1,629	1,280	1,400	7,793	60.33	
Side	415	493	557	662	499	530	3,156	24.43	
Stem	315	290	337	418	293	315	1,968	15.24	
Total	1,769	1,890	2,232	2,709	2,072	2,245	12,917	100.00	12,917

In this experiment a slightly smaller percentage of larvæ entered at the calyx end of the apple on the lime-sulphur demonstration plat than on the one-spray plat, the percentages being 6.70 and 8.49, respectively. As will be noted under the above discussion of worminess of the apples, a coarse-spray nozzle and a high pressure were used for all applications on all the sprayed plats. Such treatment would therefore be expected to result in a lower percentage of larvæ entering at the calyx end on the demonstration plat than if a mist spray had been used, as was done in the foregoing experiments. The total number of larvæ on Plats I, II, III, and IV are, respectively, 970, 3,215, 1,543, and 12,917.

In protecting the calyx end of the apple there is shown a difference between the two treatments of 1.02 per cent in favor of the demonstration, which is a greater difference than occurred in any of the other experiments. This result is probably largely due to the use of coarse-spray nozzles on all sprayed plats as mentioned above. The demonstration treatment saved a total of 95.28 per cent of the crop, which was 11.11 per cent more than that saved by the one-spray treatment. The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table XVIII.

TABLE XVIII.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentage of wormy apples. Wichita, Kans., 1911.*

Plat No.	Percentage of wormy apples.				Total number of wormy apples.	Total number of apples.
	Calyx.	Side.	Stem.	Total.		
I. Demonstration	0.32	4.11	0.29	4.72	970	20,545
III. One-spray	1.34	12.88	1.61	15.83	1,543	9,745
IV. Unsprayed	42.10	17.05	10.64	69.79	12,917	18,506

SUMMARY OF RESULTS.

The percentages of fruit free from codling moth and plum curculio injury on the demonstration, one-spray, and unsprayed plats from the several localities are given for comparison in Table XIX. The average percentage of fruit free from codling-moth injury for the four orchards gives for the demonstration treatment 96.72 per cent as against 90.76 per cent for the one-spray method, a gain of 5.96 per cent in favor of the demonstration. The average percentage of fruit free from this insect on the unsprayed plats was 52.70, making a gain in favor of the demonstration plats over the unsprayed plats of 44.02 per cent.

TABLE XIX.—*Percentages of fruit free from injury by the codling moth and plum curculio on one-spray, demonstration, and unsprayed plats in Virginia, Michigan, Delaware, and Kansas, in 1910 and 1911.*

Locality.	Codling moth.			Plum curculio.		
	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.
Fishersville, Va	99.42	99.01	84.49	94.72	94.37	90.38
Fennville, Mich	92.91	87.05	52.73	....	....	....
Camden, Del	99.27	92.83	43.40	90.37	85.69	65.13
Wichita, Kans	95.28	84.16	30.20	....	....	....
Average of four localities	96.72	90.76	52.70	92.54	90.03	77.75

In Table XX is given a summary of the results of the one-spray experiments carried out by this bureau in 1909 (Bul. 80, Part VII, Revised) for the purpose of comparison with the foregoing results of the 1910 and 1911 experiments (Table XIX).

TABLE XX.—*Percentages of fruit free from injury by the codling moth and plum curculio on demonstration, one-spray, and unsprayed plats in Arkansas, Virginia, and Michigan in 1909.*

Locality.	Codling moth.			Plum curculio.		
	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.
Siloam Springs, Ark	98.12	92.76	66.74	82.88	86.34	8.85
Crozet, Va	94.13	84.07	53.02	86.89	73.93	54.02
Mount Jackson, Va	92.74	91.68	54.00	40.82	57.90	27.23
Saugatuck, Mich	97.66	93.61	77.79	98.77	97.54	87.42
Average of four localities	96.57	91.46	65.14	83.37	77.10	49.17

In comparing Tables XIX and XX it will be seen that for the two sets of experiments the average percentages of fruit free from codling-moth injury on the sprayed plats were practically the same, while on the unsprayed plats the fruit was considerably less infested with this insect in 1909 than in 1910 and 1911. The average percentage of fruit free from this insect for the demonstration treatment in 1909 was 96.57 per cent as against 96.72 per cent in 1910 and 1911, a difference of only 0.15 per cent. In the case of the one-spray treatment there was a difference of only 0.70 per cent in the average percentages of fruit free from codling-moth injury.

Table XXI shows the total efficiency and the protection afforded to each of the different parts of the apple by the treatments for the four orchards. It will be seen from the average of the four localities that nearly 60 per cent of the total larvæ on the unsprayed plats entered through the calyx, while on the sprayed plats 83 per cent of the worms entered the fruit by way of the side, showing that the poison in the calyx is much more efficient than that on the side of the fruit.

The averages of the percentages of apples wormy at the calyx on the demonstration and the one-spray treatments are practically the same, there being a difference of only 0.3 per cent in favor of the demonstration treatment. The one-spray treatment was about one-third less effective in preventing side entrance than the demonstration treatment. Both methods were effective in reducing entrance at the stem end, the demonstration slightly more so than the one-spray.

TABLE XXI.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentages of wormy apples, Virginia, 1910, Michigan, Delaware, and Kansas, 1911.*

Locality.	Percentage of wormy apples.											
	Calyx.			Side.			Stem.			Total.		
	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.
Fishersville, Va	0.19	0.13	9.89	0.26	0.54	2.53	0.12	0.31	3.07	0.57	0.98	15.49
Fennville, Mich.[1]	.96	.86	25.62	5.98	11.64	17.95	.14	.44	3.69	7.08	12.94	47.26
Camden, Del	.03	.36	31.67	.62	5.96	18.78	.08	.84	6.15	.73	7.16	56.60
Wichita, Kans	.32	1.34	42.10	4.11	12.88	17.05	.29	1.61	10.64	4.72	15.83	69.79
Average	.37	.67	27.32	2.74	7.75	14.08	.16	.80	5.89	3.27	9.23	47.28

[1] The figures under calyx, side, and stem for Fennville are based on the number of entrance holes instead of the number of apples entered.

For the purpose of comparing the results of the experiments conducted in 1910 and 1911 with those conducted in 1909, as to the efficiency of the two methods of treatment as shown by the percentages of wormy apples, Table XXII is presented. This table shows that the results in the two sets of experiments were practically the same as to protection of the calyx and stem ends of the apple from codling-moth infestation. The one-spray method was less effective in preventing side entrance in 1910–11 than in 1909.

TABLE XXII.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentages of wormy apples. Results of experiments in 1909 compared with those in 1910–11.*

Years.	Percentage of wormy apples.											
	Calyx.			Side.			Stem.			Total.		
	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.	Demonstration.	One-spray.	Unsprayed.
1909	0.57	0.68	23.85	2.87	7.64	8.92	0.18	0.59	2.21	3.42	8.55	34.86
1910–11	.37	.67	27.32	2.74	7.75	14.08	.16	.80	5.89	3.27	9.23	47.28

CONCLUSIONS.

The results of experiments reported in the present paper corroborate those earlier obtained by the bureau (Bul. 80, Pt. VII, p. 146) as to the efficiency of the one-spray method in controlling the codling moth and plum curculio. Bringing together the results of all of the tests which represent several seasons and varied conditions, it is found that the average of the percentages of sound fruit from a single spraying is 90.64 as compared with 96.19, the average of the percentages of sound fruit on the demonstration plats receiving from three to five applications. The unsprayed plats show an average of 57.79 per cent of fruit free from codling-moth injury. The variation in percentage of sound fruit is considerably greater with plats receiving the single application than where the demonstration treatment was given, indicating, perhaps, a less degree of insurance from injury, especially under unusual seasonal conditions, as in case of injury of fruit by hail, etc., as occurred in Virginia during 1909. For the entire period the range in percentage of sound fruit on the demonstration plat is from 92.91 (Michigan, 1911) to 99.42 (Virginia, 1910) and on the one-spray the range is from 84.07 per cent (Virginia, 1909) to 99.01 per cent (Virginia, 1910).

In Prof. Gossard's work in Ohio (Bul. 191, Ohio Agr. Exp. Sta.) a single spraying resulted in 91.60 per cent of sound fruit as compared with 45.80 per cent from unsprayed trees. In West Virginia, Rumsey (Bul. 127, W. Va. Univ. Agr. Exp. Sta.) obtained by the one-spray method 97.40 per cent of fruit free from codling moth, as compared with 96.7 per cent sound fruit from four applications. In these tests the unsprayed trees showed 65.9 per cent only of sound fruit.

Dr. Felt's very valuable data obtained in New York State (Journ. Econ. Ent., Vol. V, p. 153, 1912), and covering three years of experimental work, shows for the entire period for plats receiving a single application 97.35 per cent of sound fruit; for plats receiving three applications 99.22 per cent of fruit free from worms as compared with 79.05 per cent of sound fruit on unsprayed trees.

The above data, while obtained under rather variable conditions of experiment, establish beyond doubt that a single thorough application of an arsenate-of-lead spray at once after the falling of the petals will protect from codling-moth injury a large percentage of the crop, though not quite so high a percentage as by several applications designed to protect the fruit during the entire season.

While the information as regards the plum curculio is not so full as desirable, it also appears that this insect is controlled by the single thorough treatment practically as well as by the usual three or four applications. Thus the six orchards where data were obtained by

the bureau on the curculio give an average percentage (average of percentages) of fruit free from injury on the one-spray plat of 82.62 as compared with 82.40 per cent of sound fruit on plats receiving the demonstration treatment. The percentage of sound fruit on the unsprayed trees was 55.50. Results obtained by Rumsey (l. c.) fully substantiate the foregoing. In his work a single spraying gave 87.5 per cent of crop free from injury as compared with 86.1 per cent of sound fruit on the plat receiving four applications, the check plat showing 67.9 per cent of uninjured fruit. In the case of the curculio the degree of protection afforded by spraying varies much more widely than for the codling moth, depending upon the abundance of the insects and the quantity of fruit present on the trees, as may be seen by reference to the tables on the subject in the foregoing pages and in the previous report (Bul. 80, Pt. VII).

It would therefore appear from the foregoing that for the control of the codling moth and plum curculio under eastern conditions, a single thorough spraying is about as efficient as a schedule of treatment requiring three or more applications; were these the only troubles to be considered, the orchardist would hardly be justified in making additional applications.

The reader should bear in mind, however, that in the experimental work reported applications have been made with an unusual degree of thoroughness. It will be evident that the value of a single spraying depends entirely on the extent to which the calyx cups of the fruit are filled with the poison. Perfect spraying in this regard should prevent all calyx entrance of fruit by the larvæ. As a matter of fact, in our plats sprayed most thoroughly we have not been able entirely to prevent calyx entrances, though such a degree of thoroughness has been obtained, as reported by other experimenters in the Western States. The point can not be too strongly emphasized that thoroughness is the keynote in obtaining satisfactory results from the one-spray method.

The necessity of filling the inner calyx cup with poison, as insisted upon by western entomologists, and the employment of a nozzle throwing a coarse spray, as the Bordeaux, has not been, on the whole, confirmed under eastern conditions.

It appears that as good results follow the use of nozzles throwing a fine spray as where coarse nozzles are used. It is also clear that under our conditions there is no necessity to fill the inner calyx cup to control the codling moth successfully, and indeed this is prevented by the stamen bars which remain turgid and shield the cavity below, even after the calyx lobes are nearly closed. There can be no question of the desirability of high pressure in spraying (175 to 250 pounds), and most orchardists appreciate this fact. The practical

utility of the one-spray method under eastern conditions is greatly lessened on account of the necessity in most regions of giving orchards additional applications of fungicides for the prevention of such diseases as apple scab, bitter rot, apple blotch, sooty blotch, etc. In regions where bitter rot and apple blotch are not troublesome and in the case of varieties little susceptible to apple scab, the single application would be most likely to have value, and orchardists thus situated should determine the applicability of the method under their respective conditions. Where additional sprayings are necessary for fungous diseases, an arsenical should be added, as the additional cost is slight.

One very important fact has been developed as a result of these studies, namely, the importance of great thoroughness in spraying after the falling of the petals. While this has been insisted on by entomologists for many years, yet the great extent to which the codling moth may be controlled by this one treatment has not been appreciated. The aim should be to poison the calyx cup of each and every apple on the tree, irrespective of whether subsequent treatments are to be given. Imperfect spraying at this time can not be remedied by any number of later applications.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 115, Part III.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIFE HISTORY OF THE CODLING MOTH IN THE SANTA CLARA VALLEY OF CALIFORNIA.

BY

P. R. JONES AND W. M. DAVIDSON,

Entomological Assistants, Deciduous Fruit Insect Investigations.

ISSUED JANUARY 18, 1913.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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J. F. Zimmer, W. S. Abbott, W. H. Sill, *entomological assistants, employed in enforcement of insecticide act, 1910.*

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[1] Resigned.

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LIFE HISTORY OF THE CODLING MOTH IN THE SANTA CLARA VALLEY OF CALIFORNIA.

By P. R. Jones and W. M. Davidson,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

The codling moth in California presents so many differences in life history in comparison with that which has been learned in the East, as well as so many local conditions associated with each particular valley in this State, that there has been felt the need of a more comprehensive study of its life history with the temperature conditions influencing the same.

The data presented in this paper have been collected during the past three years, 1909, 1910, and 1911, only partial records being obtained for the first year but fairly complete notes for the latter two.

The Santa Clara Valley is practically one large deciduous-fruit orchard from 60,000 to 70,000 acres in extent, lying between the Santa Cruz Range of mountains on the west and the Mount Hamilton Range on the east and extending from the San Francisco Bay just north of Alviso 50 to 60 miles south past the town of Gilroy. The valley varies in width from 5 to 20 miles.

According to the United States Weather Bureau the average mean temperature for the whole year in this region is 58.1° F., compiled from a record of 36 years. The annual mean precipitation for this time has been 14.79 inches, with practically all of the rainfall in January, February, March, November, and December. It will thus be seen that the codling moth is influenced by a low dry mean temperature with little or no rainfall during the period it is attacking the fruit.

The data for 1909 were gathered by Messrs. Dudley Moulton, formerly of this bureau, and J. R. Horton of this bureau; that of 1910 and 1911 by Mr. F. L. Young, formerly of this bureau, and by both of the authors. Miss Emma Weber has contributed many life-history observations also during the years 1910 and 1911.

An attempt has been made to follow the plan of presentation as given by Messrs. Jenne and Hammar in their respective studies on the codling moth.[1]

SEASONAL-HISTORY STUDIES OF 1909.

SPRING BROOD OF PUPÆ.

The record for this brood was made from larvæ collected January 2 in the field from under the bark on apple trees and placed in separate vials for an individual pupation record. Table I records the time of pupation, time of emergence, and length of pupal period.

TABLE I.—*Spring brood of pupæ. Length of the pupal stage for wintering larvæ collected in January, 1909, from banded trees.*

No. of individual.	Date of— Pupation.	Date of— Emergence.	Length of pupal stage.	No. of individual.	Date of— Pupation.	Date of— Emergence.	Length of pupal stage.
			Days.				*Days.*
1	Feb. 20	Apr. 17	56	17	Mar. 26	May 3	38
2	Mar. 4	...do.....	48	18	Mar. 27	...do.....	37
3	...do.....	...do.....	53	19	Mar. 29	Apr. 28	30
4	Mar. 5	...do.....	52	20	...do.....	May 3	35
5	Mar. 8	Apr. 28	51	21	...do.....	...do.....	35
6	Mar. 9	Apr. 26	48	22	Mar. 30	May 6	37
7	...do.....	...do.....	48	23	Apr. 1	May 1	30
8	...do.....	Apr. 28	50	24	...do.....	May 3	32
9	Mar. 11	...do.....	48	25	...do.....	...do.....	32
10	Mar. 12	Apr. 29	48	26	...do.....	...do.....	32
11	Mar. 13	May 1	49	27	...do.....	...do.....	32
12	Mar. 15	May 3	49	28	Apr. 6	May 10	34
13	Mar. 23	...do.....	41	29	Apr. 9	May 11	32
14	Mar. 24	Apr. 28	35	30	Apr. 12	May 4	22
15	...do.....	...do.....	35	31	...do.....	May 17	35
16	...do.....	May 1	38				

Thus the pupal stage varied from 22 to 56 days, with an average of 40.22 days. The first pupation occurred February 20 and the last April 12, while the first adult emerged April 17 and the last May 17. The pupal period, therefore, occupied the time between February 20 and May 17, or 87 days. No record was kept with regard to the sexes of either larvæ or adults. Table II shows the variations in the length of the pupal stage and is a summary of Table I.

TABLE II.—*Spring brood of pupæ. Variations in the length of the pupal stage as recorded in Table I.*

Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.
1	22	5	35	4	48	1	52
2	30	2	37	2	49	2	53
5	32	2	38	1	50	1	56
1	34	1	41	1	51		

This record is for only 31 pupæ and is somewhat irregular.

[1] Bull. 80, Pts. I and VI, and Bul. 115, Pt. I, Bur. Ent., U. S. Dept. Agr.

SPRING BROOD OF MOTHS.

No record was taken of the adult emergence of the overwintering brood in 1909 other than that recorded in Table I for the pupal stage.

FIRST GENERATION.

FIRST BROOD OF EGGS.

No record in 1909.

FIRST BROOD OF LARVÆ.

No record in 1909.

FIRST BROOD OF PUPÆ.

Larvæ were collected at intervals in June, July, and August from banded trees and placed in vials for pupation in lots of varying numbers. Table III shows the pupal period for 182 individuals. In all 207 larvæ pupated, but 25, or 12.08 per cent, perished before the adults issued.

TABLE III.—*Pupæ of the first brood. Length of the pupal stage from material collected in 1909 on banded trees.*

Number of individual.	Date of—		Length of pupal stage.	Number of individual.	Date of—		Length of pupal stage.
	Pupation.	Emergence.			Pupation.	Emergence.	
			Days.				*Days.*
1	June 25	July 13	18	38	June 26	July 16	20
2	...do.....	...do.....	18	39	...do.....	...do.....	20
3	...do.....	...do.....	18	40	...do.....	...do.....	20
4	...do.....	...do.....	18	41	...do.....	...do.....	20
5	...do.....	...do.....	18	42	...do.....	...do.....	20
6	...do.....	...do.....	18	43	...do.....	...do.....	20
7	...do.....	...do.....	18	44	...do.....	...do.....	20
8	...do.....	...do.....	18	45	...do.....	...do.....	20
9	...do.....	...do.....	18	46	...do.....	...do.....	20
10	...do.....	...do.....	18	47	...do.....	...do.....	20
11	...do.....	...do.....	18	48	...do.....	...do.....	20
12	...do.....	...do.....	18	49	...do.....	July 17	21
13	...do.....	...do.....	18	50	...do.....	...do.....	21
14	...do.....	July 14	19	51	...do.....	...do.....	21
15	...do.....	July 15	20	52	...do.....	...do.....	21
16	...do.....	...do.....	20	53	...do.....	...do.....	21
17	...do.....	...do.....	20	54	...do.....	July 19	23
18	...do.....	...do.....	20	55	...do.....	July 20	24
19	...do.....	July 16	21	56	June 28	July 16	18
20	...do.....	...do.....	21	57	...do.....	...do.....	18
21	...do.....	...do.....	21	58	...do.....	...do.....	18
22	...do.....	July 19	24	59	...do.....	...do.....	18
23	...do.....	July 26	31	60	...do.....	...do.....	18
24	June 26	July 14	18	61	...do.....	...do.....	18
25	...do.....	...do.....	18	62	...do.....	July 17	19
26	...do.....	...do.....	18	63	...do.....	...do.....	19
27	...do.....	...do.....	18	64	...do.....	...do.....	19
28	...do.....	...do.....	18	65	...do.....	...do.....	19
29	...do.....	...do.....	18	66	...do.....	...do.....	19
30	...do.....	...do.....	18	67	...do.....	...do.....	19
31	...do.....	July 15	19	68	...do.....	...do.....	19
32	...do.....	...do.....	19	69	...do.....	...do.....	19
33	...do.....	July 16	20	70	...do.....	...do.....	19
34	...do.....	...do.....	20	71	...do.....	...do.....	19
35	...do.....	...do.....	20	72	...do.....	...do.....	19
36	...do.....	...do.....	20	73	...do.....	...do.....	19
37	...do.....	...do.....	20	74	...do.....	...do.....	19

TABLE III.—*Pupæ of the first brood. Length of the pupal stage from material collected in 1909 on banded trees*—Continued.

Number of individual.	Date of— Pupation.	Date of— Emergence.	Length of pupal stage.	Number of individual.	Date of— Pupation.	Date of— Emergence.	Length of pupal stage.
			Days.				*Days.*
75	June 28	July 17	19	129	July 6	July 26	20
76	...do.....	...do.....	19	130	...do.....	July 27	21
77	...do.....	...do.....	19	131	...do.....	July 28	22
78	...do.....	...do.....	19	132	...do.....	...do.....	22
79	...do.....	...do.....	19	133	July 9	July 31	22
80	...do.....	...do.....	19	134	July 10	July 29	19
81	...do.....	...do.....	19	135	July 13	July 28	15
82	...do.....	...do.....	19	136	...do.....	July 31	18
83	...do.....	July 19	21	137	...do.....	...do.....	18
84	...do.....	...do.....	21	138	...do.....	Aug. 4	22
85	...do.....	...do.....	21	139	...do.....	Aug. 5	23
86	...do.....	...do.....	21	140	July 14	...do.....	22
87	...do.....	...do.....	21	141	July 22	Aug. 14	23
88	...do.....	...do.....	21	142	July 26	Aug. 17	22
89	...do.....	...do.....	21	143	July 29	Aug. 21	23
90	...do.....	...do.....	21	144	July 13	July 31	18
91	...do.....	...do.....	21	145	...do.....	Aug. 3	21
92	...do.....	...do.....	21	146	July 14	...do.....	20
93	...do.....	...do.....	21	147	...do.....	Aug. 4	21
94	...do.....	...do.....	21	148	July 15	Aug. 3	19
95	...do.....	...do.....	21	149	...do.....	Aug. 4	20
96	...do.....	...do.....	21	150	...do.....	...do.....	20
97	...do.....	July 21	23	151	July 16	Aug. 3	18
98	...do.....	July 22	24	152	...do.....	Aug. 4	19
99	...do.....	...do.....	24	153	...do.....	Aug. 5	20
100	June 29	July 16	17	154	...do.....	...do.....	20
101	...do.....	...do.....	17	155	...do.....	Aug. 6	21
102	...do.....	July 17	18	156	July 17	Aug. 5	19
103	...do.....	July 19	20	157	...do.....	Aug. 7	21
104	...do.....	...do.....	20	158	July 19	Aug. 5	17
105	...do.....	...do.....	20	159	...do.....	Aug. 6	18
106	...do.....	...do.....	20	160	...do.....	...do.....	18
107	...do.....	...do.....	20	161	...do.....	Aug. 9	21
108	...do.....	July 20	21	162	July 22	...do.....	18
109	...do.....	...do.....	21	163	...do.....	Aug. 12	21
110	...do.....	July 21	22	164	...do.....	Aug. 13	22
111	...do.....	...do.....	22	165	...do.....	...do.....	22
112	...do.....	July 28	29	166	...do.....	Aug. 16	25
113	June 30	July 19	19	167	July 24	Aug. 18	25
114	...do.....	July 20	20	168	July 26	...do.....	23
115	...do.....	...do.....	20	169	...do.....	Aug. 20	25
116	...do.....	...do.....	20	170	July 31	Aug. 17	17
117	...do.....	July 22	22	171	Aug. 3	...do.....	14
118	...do.....	...do.....	22	172	...do.....	...do.....	22
119	July 1	July 20	19	173	Aug. 10	Aug. 25	20
120	...do.....	July 21	20	174	Aug. 11	Aug. 30	13
121	...do.....	...do.....	20	175	...do.....	Aug. 24	16
122	...do.....	July 22	21	176	...do.....	Aug. 27	17
123	...do.....	...do.....	21	177	Aug. 12	...do.....	15
124	July 2	July 21	19	178	Aug. 16	Aug. 31	15
125	...do.....	July 22	20	179	...do.....	Sept. 1	16
126	...do.....	July 23	21	180	Aug. 17	Sept. 3	17
127	...do.....	...do.....	21	181	...do.....	...do.....	17
128	July 3	...do.....	20	182	...do.....	...do.....	17

Summarizing the above records we find the earliest pupa on June 25 and the latest August 17. The first adult emerged on July 13 and the last September 3. The shortest pupal period was 13 days, the longest 31, and the average 19.84 days. No record with regard to the sex of larvæ or adults was taken. Table IV shows the length of the pupal stage summarized.

TABLE IV.—*Pupæ of the first brood. Variations in the pupal period. Summary of Table III.*

Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.
1	13	31	19	4	24	1	29
1	14	39	20	3	25	....	30
3	15	35	21	....	26	1	31
2	16	13	22	....	27		
8	17	6	23	....	28	182	
34	18						

FIRST BROOD OF MOTHS.

Time of emergence.—Larvæ and pupæ were collected from under bands on apple trees on June 21, June 28, July 6, and thereafter twice a week until September 20, when the last collection was made. Figure 27 shows graphically the adult emergence of the first-brood moths from this material and figure 28 the percentage which passed

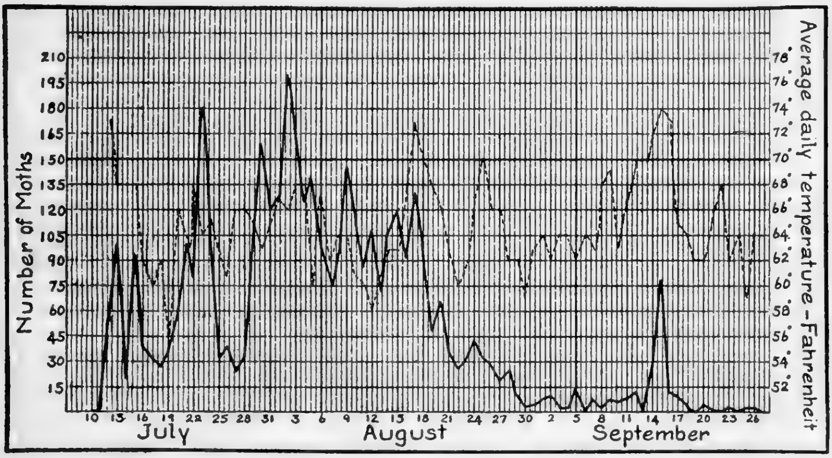

FIG. 27.—Diagram showing emergence of moths, derived from band-record material collected in 1909. (Original.)

the winter in the larval stage. They also record the daily emergence of these moths from July 12, 1909, to June 9, 1910. Table V shows the adult emergence for the total number of moths of the first brood, including both those from the general band record and those from the individual pupation records.

TABLE V.—*Moths of the first brood; total emergence.*

Date.	Number emerged.	Date.	Number emerged.	Date.	Number emerged.	Date.	Number emerged.
July 12	55	July 31	124	Aug. 19	48	Sept. 8	2
July 13	111	Aug. 1	130	Aug. 20	68	Sept. 9	8
July 14	27	Aug. 2	199	Aug. 21	38	Sept. 10	7
July 15	101	Aug. 3	168	Aug. 22	27	Sept. 11	8
July 16	68	Aug. 4	130	Aug. 23	30	Sept. 12	13
July 17	60	Aug. 5	144	Aug. 24	45	Sept. 14	28
July 18	28	Aug. 6	101	Aug. 25	34	Sept. 15	78
July 19	56	Aug. 7	76	Aug. 26	29	Sept. 16	14
July 20	65	Aug. 8	96	Aug. 27	22	Sept. 17	10
July 21	107	Aug. 9	148	Aug. 28	25	Sept. 18	1
July 22	87	Aug. 10	114	Aug. 29	12	Sept. 20	3
July 23	183	Aug. 11	87	Aug. 30	4	Sept. 23	1
July 24	105	Aug. 12	108	Aug. 31	5	Sept. 25	2
July 25	32	Aug. 13	74	Sept. 1	8	Sept. 26	2
July 26	41	Aug. 14	106	Sept. 2	9		
July 27	25	Aug. 15	119	Sept. 3	6		4,359
July 28	35	Aug. 16	92	Sept. 4	2		
July 29	101	Aug. 17	134	Sept. 5	15		
July 30	160	Aug. 18	103	Sept. 7	8		

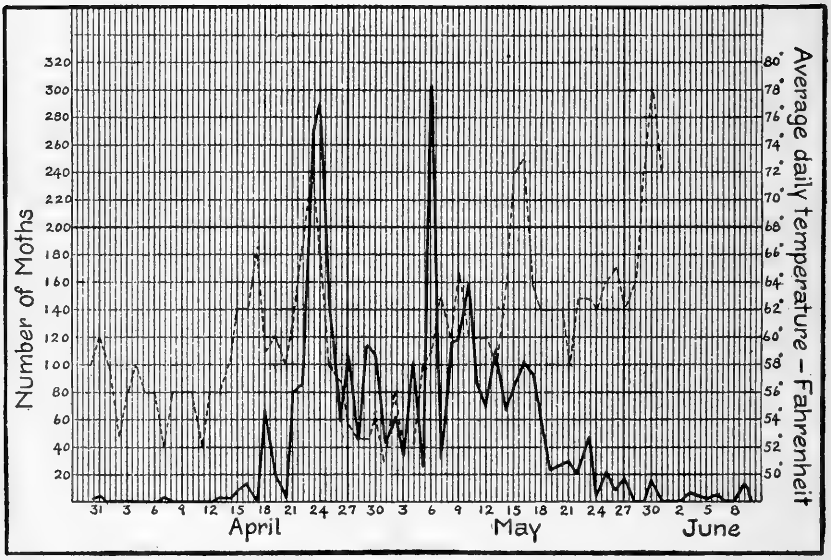

FIG. 28.—Diagram showing emergence of moths, derived from band-record material collected in 1909. (Original.)

It is therefore apparent that maximum emergence took place during the period of from July 13 to August 18, and that thereafter the emergence was drawn out all through the balance of August and up to September 26.

SECOND GENERATION.

SECOND BROOD OF EGGS.

No further observations on the life history of the codling moth were taken in 1909.

SEASONAL-HISTORY STUDIES OF 1910.

SPRING BROOD OF PUPÆ.

Time of pupation.—The earliest pupation observed during the spring of 1910 in the breeding jars was on March 3 and the latest pupation April 25. Considering the time when the first adult emerged on March 30, and adding the average length of the pupal stage, or 40.7 days, the earliest pupation must have taken place about February 18. As the latest adult of the spring brood of moths emerged on June 9, the last overwintering larvæ must have pupated about May 1.

Pupæ were therefore in evidence from February 18 to June 9, a period of 111 days.

Figure 29 shows when the first, last, and maximum pupation took place in the rearing cages, as well as the daily mean temperature, and

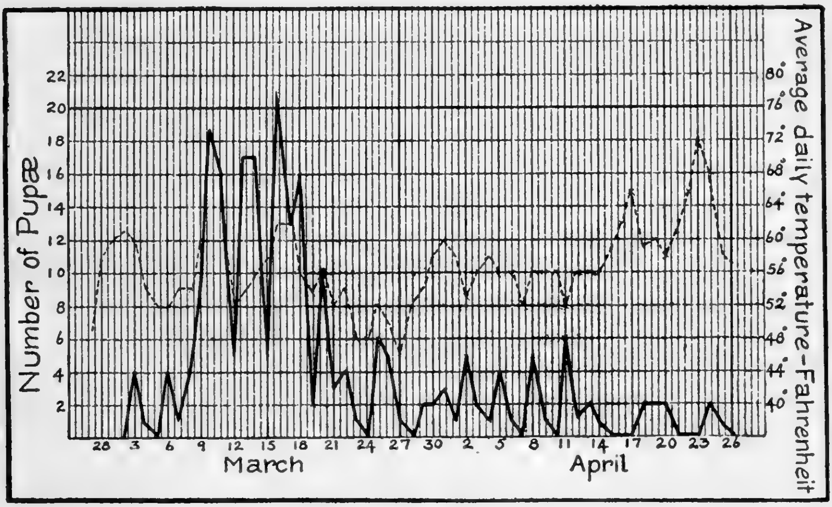

FIG. 29.—Diagram showing time of pupation of spring brood of pupæ, 1910. (Original.)

that the overwintering larvæ pupated from March 3 until April 25. Most of the larvæ pupated during the period from March 8 to 25.

An examination of figure 29 shows that the sudden increase in daily mean temperature after February 20 probably started overwintering larvæ pupating. The high daily mean temperature from March 8 to 20 explains the maximum time of pupation, and shows that a drop or increase of 5 degrees in mean temperature usually influenced accordingly the number of larvæ pupating. The period of low mean temperature from March 20 to 27 stopped pupation to some extent, but it was started again in the remaining days of March and in early April. By this time practically all of the larvæ had pupated, and the warm period following has no bearing on the time of pupation.

Length of spring pupal stage.—Records were obtained on 229 pupæ which were kept in vials under natural conditions (see Table VI):

TABLE VI.—*Spring brood of pupæ. Length of the pupal period for overwintering larvæ collected during 1909 on banded trees.*

No. of individual.	Sex of larva.	Date of—		Sex of moth.	Length of pupal stage.	No. of individual.	Sex of larva.	Date of—		Sex of moth.	Length of pupal stage.
		Pupation.	Emergence.		*Days.*			Pupation.	Emergence.		*Days.*
1	♂	Mar. 3	Apr. 16	♂	44	71		Mar. 13	Apr. 24		42
2	♂	do.	do.	♂	44	72		do.	do.		42
3	♂	do.	do.	♂	44	73		do.	do.		42
4	♀	do.	Apr. 18	♀	46	74		do.	do.		42
5		Mar. 4	Apr. 19		46	75	♂	do.	Apr. 25	♂	43
6	♂	Mar. 5	May 9	♂	34	76	♀	do.	do.	♀	43
7	♂	Mar. 6	Apr. 19	♂	44	77	♂	do.	Apr. 23	♂	44
8	♀	do.	Apr. 20	♀	45	78		do.	Apr. 28		41
9	♂	do.	Apr. 22	♂	47	79	♀	do.	Apr. 23	♀	41
10	♂	do.	do.	♂	47	80	♀	do.	Apr. 25	♀	43
11	♀	Mar. 7	do.	♀	46	81		do.	do.		43
12		Mar. 8	do.		45	82	♂	do.	do.	♂	43
13		do.	do.		45	83	♀	do.	do.	♀	43
14		do.	do.		45	84	♂	Mar. 14	Apr. 24	♂	41
15		do.	May 9		31	85	♀	do.	do.	♀	41
16		do.	Apr. 21		44	86	♂	do.	do.	♂	41
17	♂	Mar. 9	Apr. 22	♂	44	87	♂	do.	do.	♂	41
18		do.	Apr. 27		49	88		do.	Apr. 23		40
19	♀	do.	Apr. 22	♀	44	89		do.	do.		40
20	♂	do.	Apr. 23	♂	45	90	♀	do.	Apr. 25	♀	42
21	♀	do.	do.	♀	45	91	♀	do.	Apr. 24	♀	41
22	♀	do.	Apr. 22	♀	44	92	♂	do.	Apr. 27	♂	44
23		do.	do.		44	93	♀	do.	Apr. 24	♀	41
24	♀	do.	Apr. 23	♀	45	94	♀	do.	Apr. 25	♀	42
25		do.	do.		45	95		do.	Apr. 24		41
26	♂	do.	do.	♂	45	96		do.	do.		41
27	♀	Mar. 10	Apr. 24	♀	45	97	♂	do.	do.	♂	41
28		do.	Apr. 23		44	98	♀	do.	Apr. 25	♀	42
29	♀	do.	do.	♀	44	99		do.	Apr. 23		40
30	♂	do.	do.	♂	44	100	♂	do.	do.	♂	40
31		do.	Apr. 21		42	101	♂	Mar. 15	Apr. 24	♂	40
32		do.	Apr. 23		44	102	♂	do.	do.	♂	40
33	♀	do.	Apr. 24	♀	45	103	♀	do.	Apr. 25	♀	41
34		do.	do.		45	104		do.	do.		41
35	♀	do.	do.	♀	45	105	♀	do.	Apr. 27	♀	43
36	♀	do.	Apr. 23		44	106		Mar. 16	Apr. 25		40
37		do.	do.		44	107	♂	do.	do.	♀	40
38	♂	do.	Apr. 21	♂	42	108	♀	do.	do.	♀	40
39	♀	do.	Apr. 23	♀	44	109	♀	do.	Apr. 27	♀	42
40		do.	Apr. 24	♂	43	110		do.	May 16		61
41		do.	Apr. 23		44	111	♂	do.	Apr. 27	♂	42
42	♂	do.	do.	♂	44	112	♀	do.	Apr. 26	♀	41
43	♂	do.	do.	♂	44	113	♂	do.	Apr. 25	♂	40
44	♀	do.	Apr. 21	♀	42	114	♀	do.	Apr. 28	♀	43
45		do.	Apr. 23		44	115		do.	Apr. 27		42
46	♂	Mar. 11	Apr. 24	♂	44	116	♀	do.	do.	♀	42
47	♂	do.	Apr. 23	♂	43	117		do.	Apr. 25		40
48	♀	do.	do.	♀	43	118	♀	do.	Apr. 28	♀	43
49	♂	do.	do.	♂	43	119	♀	do.	Apr. 25	♀	40
50		do.	do.		43	120		do.	Apr. 24		39
51		do.	Apr. 24		44	121		do.	Apr. 25		40
52		do.	Apr. 21		41	122	♂	do.	do.	♂	40
53		do.	do.		41	123		do.	do.		40
54		do.	Apr. 23		43	124	♂	do.	Apr. 27	♂	42
55	♀	do.	Apr. 24	♀	44	125		do.	Apr. 25		40
56		do.	Apr. 23		43	126	♂	Mar. 17	Apr. 28	♂	42
57		do.	Apr. 24		44	127	♂	do.	Apr. 25	♂	39
58	♀	do.	do.	♀	44	128	♂	do.	Apr. 27	♂	41
59	♀	do.	Apr. 23	♀	43	129		do.	Apr. 25		39
60		do.	do.		43	130	♀	do.	May 2	♀	46
61	♂	do.	Apr. 24	♂	44	131	♂	do.	Apr. 29	♂	43
62	♂	Mar. 12	Apr. 23	♂	42	132		do.	Apr. 28		42
63		do.	do.		42	133	♀	do.	Apr. 29	♀	43
64	♀	do.	Apr. 24	♀	43	134	♂	do.	Apr. 27	♂	41
65	♀	do.	do.		43	135		do.	Apr. 30		40
66	♂	do.	do.	♂	43	136		do.	do.		44
67	♂	Mar. 13	do.	♂	42	137		do.	Apr. 28		42
68	♀	do.	do.	♀	42	138	♀	do.	Apr. 29	♀	43
69	♀	do.	do.	♀	42	139	♀	Mar. 18	do.	♀	42
70		do.	Apr. 25		43	140		do.	Apr. 27		40

TABLE VI.—*Spring brood of pupæ. Length of the pupal period for overwintering larvæ collected during 1909 on banded trees*—Continued.

No. of individual.	Sex of larva.	Date of— Pupation.	Date of— Emergence.	Sex of moth.	Length of pupal stage.	No. of individual.	Sex of larva.	Date of— Pupation.	Date of— Emergence.	Sex of moth.	Length of pupal stage.
					Days.						*Days.*
141	♀	Mar. 18	Apr. 29	♀	42	186	......	Mar. 27	May 4	......	38
142	......	...do...	...do...	......	42	187	♂	Mar. 29	...do...	♂	36
143	......	...do...	Apr. 28	......	41	188	......	...do...	May 5	......	37
144	♀	...do...	...do...	♀	41	189	♀	Mar. 30	May 6	♀	37
145	♂	...do...	...do...	♂	41	190	♀	...do...	May 5	♀	36
146	......	...do...	Apr. 25	......	38	191	......	Mar. 31	May 6	......	36
147	......	...do...	May 4	......	47	192	♂	...do...	May 7	♀	37
148	♂	...do...	Apr. 28	♂	41	193	♂	...do...	May 6	♂	36
149	♀	...do...	May 2	♀	45	194	♀	...do...	May 8	♀	38
150	♂	...do...	Apr. 29	♂	42	195	♀	Apr. 1	May 7	♀	36
151	♀	...do...	May 2	♀	45	196	♀	Apr. 2	May 9	♀	37
152	♂	...do...	Apr. 28	♂	41	197	♂	...do...	May 7	♂	35
153	♂	...do...	Apr. 30	♂	43	198	♂	...do...	May 9	♂	37
154	......	...do...	May 3	......	46	199	......	...do...	May 7	......	35
155	♀	Mar. 19	...do...	♀	45	200	♀	...do...	May 9	♀	37
156	♀	...do...	...do...	♀	45	201	♀	Apr. 3	...do...	♀	36
157	♀	Mar. 20	...do...	♀	44	202	♂	...do...	May 10	♂	37
158	......	...do...	...do...	......	44	203	......	Apr. 4	May 6	......	32
159	♂	...do...	May 2	♂	43	204	♂	Apr. 5	May 9	♂	34
160	♀	...do...	May 3	♀	44	205	♀	...do...	May 10	♀	35
161	♀	...do...	...do...	♀	44	206	♀	...do...	May 8	♀	30
162	......	...do...	Apr. 29	......	40	207	♀	Apr. 6	May 10	♀	34
163	♀	...do...	May 3	♀	44	208	......	Apr. 8	...do...	......	32
164	♂	...do...	May 2	♂	43	209	♂	...do...	...do...	♂	32
165	♂	...do...	Apr. 30	♂	41	210	......	...do...	May 11	......	33
166	......	...do...	...do...	......	41	211	♀	...do...	May 10	♀	32
167	♂	Mar. 21	...do...	♂	40	212	♀	Apr. 9	May 13	♀	34
168	♂	...do...	May 4	♂	44	213	♂	Apr. 11	May 14	♂	33
169	♂	...do...	Apr. 30	♂	40	214	♀	...do...	May 13	♀	32
170	♂	Mar. 22	Apr. 29	♂	38	215	♀	...do...	May 14	♀	33
171	......	...do...	May 4	......	43	216	......	...do...	May 11	......	30
172	♂	...do...	Apr. 24	♂	41	217	♀	...do...	May 14	♀	33
173	♂	...do...	Apr. 29	♂	38	218	♀	...do...	May 12	♀	32
174	♀	Mar. 23	May 3	♀	41	219	♂	Apr. 12	...do...	♂	30
175	♀	Mar. 25	Apr. 30	♀	36	220	♀	Apr. 13	May 15	♀	32
176	♀	...do...	May 15	♀	51	221	......	...do...	May 13	......	30
177	......	...do...	May 2	......	38	222	♂	Apr. 14	...do...	♂	29
178	♀	...do...	May 6	♀	42	223	♀	Apr. 18	May 17	♀	29
179	......	...do...	May 4	......	40	224	......	...do...	...do...	......	29
180	......	...do...	Apr. 30	......	36	225	......	Apr. 20	May 20	......	30
181	♀	Mar. 26	May 4	♀	39	226	♀	...do...	...do...	♀	30
182	♀	...do...	Apr. 30	♀	35	227	......	Apr. 24	May 24	......	30
183	♀	...do...	May 3	♀	39	228	♀	...do...	May 25	♀	31
184	♀	...do...	May 2	♀	37	229	♂	Apr. 25	May 24	♂	29
185	♀	...do...	May 3	♀	38						

The variations in the length of the pupal periods, as shown in Table VI, extended from 29 to 61 days.

TABLE VII.—*Spring brood of pupæ. Variations in the length of the pupal period for 229 pupæ as recorded in Table VI.*

Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.	Number of pupæ.	Days.
4	29	4	35	28	41	3	47
6	30	8	36	28	42	1	49
2	31	8	37	28	43	1	51
7	32	8	38	34	44	1	61
5	33	4	39	18	45		
4	34	22	40	5	46		

An examination of Table VI shows that larvæ pupating in March usually required several days longer for the pupal periods than larvæ pupating in April.

Table VIII shows the summary of observations recorded in Table VI and that the average length of the pupal period was 40.7 days for the 229 pupæ.

TABLE VIII.—*Spring brood of pupæ. Summary of pupal periods of Table VI.*

Observations.	Days.
Maximum	61
Minimum	29
Average	40.7

Comparative length of pupal periods of male and female larvæ.—An attempt was made to ascertain the sex of the future moth while in the larval state, by the occurrence of two black spots on the dorsum of one of the posterior abdominal segments, the presence of which indicated a male. Records were kept on each individual that could be observed well in its cocoon, and in each instance the moth issued true to the sex ascribed to it while in the larval state.

In comparing the total pupal periods for 64 males and 87 females, the average length of the pupal stage for males was found to be 40.5 days and that of the female to be 40.6 days. This difference was not sufficient to warrant any conclusion during the 1910 season as to the respective lengths of the pupal periods of the males in comparison with that of the females.

Temperature conditions.—The temperature conditions influencing the pupal periods of the spring brood of pupæ are summarized in Table IX:

TABLE IX.—*Spring brood of pupæ. Temperature conditions influencing the pupal period.*

	Maximum.	Minimum.	Mean.	Departure from normal.
	°*F.*	°*F.*	°*F.*	°*F.*
March	66.2	44.5	55.4	+1.7
April	70.2	46.0	58.1	+1.4
May	75.9	48.7	62.3	+1.6
Average	70.7	46.4	58.6	

SPRING BROOD OF MOTHS.

Time of emergence of moths in the spring.—Figure 2 shows graphically the time of emergence and the relative abundance of moths of the spring brood with the corresponding daily mean temperature in degrees Fahrenheit. The records for these observations are given in Table X.

TABLE X.—*Emergence of spring moths from wintering material collected on banded trees during 1909.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
Mar. 30	1	Apr. 17	0	May 5	28	May 23	56
Mar. 31	2	Apr. 18	60	May 6	329	May 24	5
Apr. 1	0	Apr. 19	23	May 7	36	May 25	28
Apr. 2	0	Apr. 20	8	May 8	127	May 26	12
Apr. 3	0	Apr. 21	87	May 9	136	May 27	21
Apr. 4	0	Apr. 22	99	May 10	185	May 28	0
Apr. 5	0	Apr. 23	307	May 11	97	May 29	0
Apr. 6	0	Apr. 24	333	May 12	84	May 30	27
Apr. 7	1	Apr. 25	152	May 13	127	May 31	0
Apr. 8	0	Apr. 26	61	May 14	74	June 1	0
Apr. 9	0	Apr. 27	125	May 15	102	June 2	0
Apr. 10	0	Apr. 28	58	May 16	122	June 3	8
Apr. 11	0	Apr. 29	130	May 17	118	June 4	2
Apr. 12	0	Apr. 30	121	May 18	77	June 5	1
Apr. 13	1	May 1	45	May 19	25	June 6	6
Apr. 14	1	May 2	76	May 20	30	June 7	0
Apr. 15	7	May 3	48	May 21	32	June 8	0
Apr. 16	18	May 4	111	May 22	21	June 9	20

The emergence of the first moths on March 30 and 31 was undoubtedly caused by the sudden rise in mean temperature about this time, as will be seen from figure 1. Also the period of low mean temperature during the first 12 days of April stopped emergence to a minimum. A rise in temperature from April 12 to 18 brought forth moths again, and the high period of mean temperature about April 22 to 24 caused the first absolute maximum of emergence, then a drop in temperature and a corresponding cessation of emergence, and finally the second absolute maximum emergence on May 6, which was caused by high mean temperature about that period and the rest of the month. After May 18 practically all of the moths had emerged and no further conclusions could be drawn of the influence of temperature on the emergence of spring-brood moths. Most of the moths emerged during the period from April 15 to May 20 and the maximum period thus embraced about 35 days. The whole period of emergence of spring-brood moths extended from March 30 to June 9, a period of 72 days.

Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the preceding year.—In Table XI is given a detailed account of the band collections of 1909, including the dates of collection, relative number of pupæ and larvæ, daily emergence of the first brood moths for that year (1909), and the daily emergence of the spring-brood moths which came from the overwintering larvæ, the latter being both first and second brood larvæ of 1909. In Table XI is given also the relative percentage of moths emerging from each separate band collection for the years 1909 and 1910, including totals for each year and a summary of the total moths emerging for both years. As previously recorded by Mr. Hammar,[1] the time the

[1] Bureau of Entomology, Bul. No. 80, Part VI.

larvæ leave the fruit in the fall has no bearing upon the time of emergence of the moths in the following spring; in fact, some of the larvæ which left the fruit the latest in the fall of 1909 emerged as moths the earliest in the spring of 1910. The division line between broods probably occurred about August 12 to 16, and by examining the table of the emergence record of 1910 no difference can be seen between the respective dates of emergence of the moths.

Relative percentage of larvæ wintering from band material and percentage emerging as first-brood moths the year the larvæ were collected.—An examination of Table XI shows that 65.3 per cent was the highest number that emerged in 1909 for any single band collection and 6 per cent the lowest. No moths emerged in 1909 from band collections later than August 31. Of the total number of pupæ and larvæ collected from all the bands for the entire season only 28.31 per cent emerged as first-brood moths for the year 1909. One curious fact of the percentages that emerged in 1909 from each band collection during that year was the sudden rise in percentage to 39.6 for the lot collected August 19, after the percentage column had begun to dwindle to smaller proportions. It will be seen from a glance at the table that the moths emerged from this collection from September 11 to 16 and this may be explained by the very high mean temperature during this period. Just why the high temperature influenced this one collection and none of the earlier or later collections is difficult to explain, except that this particular collection was the first important collection of second-brood larvæ.

A very unfortunate thing happened during the winter of 1909–10, in that the first three jars and also jar C–10 were nearly filled with water and consequently all of the overwintering larvæ were drowned before being noticed. This caused to a great extent the small total percentage emerging in 1910, or 21.25 per cent, which might have been 30 or 35 per cent.

The total percentage emerging for both years 1909–10 from the total amount of larvæ and pupæ collected was 49.56 per cent, the remainder having died naturally or were in the four jars filled with water. It will be noticed that the highest total percentage emerging for both years from any separate band collection was 88.4 per cent and was from the previously mentioned collection on August 19, 1909.

TABLE XI.—*Adult emergence of the first and spring broods from band material collected in 1909.*

Jar No.	Date of collection.	Number collected.		Total.	Emergence.					
		Larvæ.	Pupæ.		1909.		1910.		1909–10.	
					Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
	1909.									
C-3	June 21....	1,602	215	1,817	403	23.8	....	....	403	23.8
C-4-5	June 28....	2,276	79	2,355	678	28.8	....	....	678	28.8
C-7	July 6.....	946	159	1,105	722	65.3	....	....	722	65.3
C-8	July 9.....	804	93	897	427	47.6	122	13.6	549	61.2
C-9	July 12....	761	59	820	295	35.9	121	14.7	416	50.6
C-10	July 15....	885	68	953	496	52.0	....	....	496	52.0
C-11	July 19....	919	48	967	433	44.7	141	14.6	574	59.3
C-12	July 22....	536	37	573	260	45.3	74	11.1	334	56.4
C-13	July 26....	505	30	535	148	26.5	143	26.5	291	53.0
C-14	July 29....	350	22	372	79	21.2	133	35.7	212	56.9
C-15	Aug. 2.....	297	22	319	48	15.0	115	36.0	163	51.0
C-16	Aug. 5.....	180	16	196	4	2.0	42	21.4	46	23.4
C-18	Aug. 9.....	185	7	192	26	13.5	47	24.4	73	37.9
C-19	Aug. 12...	115	10	125	9	7.2	82	65.6	91	72.8
C-21	Aug. 16...	112	4	116	18	15.5	55	48.2	73	63.7
C-22	Aug. 19...	262	2	264	105	39.6	129	48.8	234	88.4
C-23	Aug. 23...	383	0	383	18	4.6	193	50.4	211	55.0
C-24	Aug. 26...	403	3	406	5	1.2	223	54.9	228	56.1
C-25	Aug. 31...	477	4	481	3	.6	267	55.5	270	56.1
C-26	Sept. 2....	371	4	375	....	....	210	56.0	210	56.0
C-27	Sept. 6....	580	0	580	....	....	257	44.3	257	44.3
C-28	Sept. 9....	381	0	381	....	....	258	66.9	258	66.9
C-29	Sept. 13...	253	0	253	....	....	328	72.4	328	72.4
C-30	Sept. 16...	359	1	360	....	....	157	43.6	157	43.6
C-31	Sept. 20...	290	0	290	....	....	116	40.0	116	40.0
	Total ..	14,232	883	15,115	4,177	27.63	3,213	21.25	7,390	48.88

Time during the day when moths emerged.—No tabulated record was kept to show the time during the day when most of the moths emerged, but observations showed that they issued in numbers after 4 p. m. and supposedly during the night. Few emerged during the period from morning after 9 o'clock until in the evening. The emergence record was therefore usually taken each morning before 9 a. m. and included moths of the evening and night before. This seems at variance with the records obtained in 1911.

Period of oviposition.—The first moths that appeared the latter part of March failed to oviposit since only a few individuals had appeared until April 18. No difficulty was experienced in obtaining eggs in confinement when a number of moths were placed in a cage at a time. No eggs could be obtained from single pairs of spring-brood moths as was possible later with those of the first brood and hence no data was obtained as to the number of eggs a single female can deposit.

The first eggs were obtained April 26 or about from 3 to 4 days after moths began to emerge in numbers. The period of low mean temperature from April 26 to May 5 (see fig. 28) caused very few eggs to be deposited, but by May 7 and from then on until the end of the month large numbers were obtained. Oviposition in the field probably extended from April 10 to June 20 (about 10 days after the last moth appeared), or a period of about 80 days, this giving a wide

range for developing first-brood larvæ. Maximum oviposition occurred from May 7 to 20, or from 15 to 30 days after full bloom on most varieties of apples.

No records were kept as to the length of the oviposition period for individuals. Oviposition was observed throughout the day, but chiefly in the evening and at night.

FIRST GENERATION.

FIRST BROOD OF EGGS.

Incubation period.—Practically all of the spring brood of moths that emerged were utilized for egg records and were placed in Riley cages, where they oviposited on apples suspended from strings. The apples were removed each morning and transferred to jelly glasses and kept under serial numbers. It was found necessary to cover the glasses with a fine piece of cloth in order to keep out hymenopterous egg parasites.

Table XII shows a complete record for 720 eggs deposited from April 26 to May 17.

TABLE XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages.*

No. of apple.	Number of eggs.	Date of deposition.	Red ring. Date of appearance.	Red ring. Number of eggs.	Black spot. Date of appearance.	Black spot. Number of eggs.	Hatched. Date.	Hatched. Number of eggs.	Length of egg stage.
									Days.
1	8	Apr. 26	May 1 May 2	5 3	May 10 May 11	1 6	May 13	8	17
2	18	May 7	May 9 May 10 May 15	4 7 1	May 16 May 17	6 4	May 17 May 18	1 15	10 11
3	20	May 8	May 10 May 11 May 12 May 13	1 2 9 7	May 17 May 18	9 7	May 18 May 19 May 20	3 8 4	10 11 12
4	22	May 9	May 12 May 13 May 14 May 16 May 17	6 8 1 1 2	May 17 May 18 May 20	3 15 3	May 20 May 21 May 22 May 23 May 24	6 2 6 1 2	11 12 13 14 15
5	2	May 10	May 13	2	May 18	2	May 20	2	10
6	3	May 11	May 14	2	May 20	3	May 22	3	11
7	218	May 13	May 13 May 14 May 15 May 16 May 17 May 18	18 4 71 53 25 6	May 19 May 20 May 21 May 22 May 23 May 24	3 35 68 102 1 3	May 22 May 23 May 24 May 25 May 26	10 44 30 42 66	9 10 11 12 13
8	186	May 18	May 19 May 20 May 21 May 24 May 26	5 1 17 34 7	May 26 May 27 May 28	27 50 30	May 28 May 29 May 30 June 1	45 26 30 14	10 11 12 14
9	16	May 19	May 21 May 24 May 26	3 6 6	May 28 May 29	9 6	June 1	14	12
10	52	May 20	May 24 May 25	11 20	May 26 May 27 May 28	30 16 4	May 28 May 30 June 1	25 15 10	8 10 11
11	26	May 21	May 22 May 23 May 24	3 2 4	May 28 May 29 May 30	2 16 3	May 30 June 1	18 4	9 10
12	1	May 22	....	....	May 30	1	May 31	1	9

TABLE XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages*—Contd.

No. of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date.	Number of eggs.	
									Days.
13	132	May 14	May 14	12	May 20	15	May 23	22	9
			May 15	13	May 21	23	May 24	39	10
			May 16	29	May 22	61	May 25	30	11
			May 17	16	May 23	30	May 26	16	12
			May 18	36			May 27	12	13
			May 19	12					
14	69	May 15	May 16	10	May 20	1	May 25	25	10
			May 17	30	May 21	3	May 26	23	11
			May 18	11	May 22	15	May 27	13	12
			May 20	6	May 24	31			
					May 25	14			
15	24	May 16	May 17	1	May 20	2	May 24	2	8
			May 18	14	May 22	5	May 26	2	10
			May 19	2	May 24	9	May 27	3	11
					May 26	3	May 29	22	13
16	100	May 17	May 18	23	May 24	1	May 27	11	10
			May 19	43	May 26	32	May 28	55	11
			May 20	16	May 27	48	May 29	10	12
			May 22	8					

In all 897 eggs were deposited and 720 hatched, or slightly over 80 per cent. The maximum length of the egg stage was 17 days, the minimum 8, and the average 12.4 days. (See Table XIII.) The red ring appeared after from 1 to 8 days but averaged from 2 to 5 days. The black spot appeared from 6 to 15 days after the eggs were deposited but usually appeared after 8 to 9 days.

An examination of Table XII shows that after the first lot of eggs had been deposited the length of the egg stage was fairly constant throughout the oviposition period of the spring moths. As has been observed by other writers, eggs which were deposited on the same day sometimes varied from one to three days in the length of the egg stage. This was due to differences in embryological development of the eggs within the body of the female.

TABLE XIII.—*Incubation period of first-brood eggs. Summary of Table XII.*

Observations.	Days of incubation.
Average.........	12.4
Maximum.......	17
Minimum........	8

A summary of the incubation periods for the total number of eggs deposited by the spring-brood moths is shown in Table XIV.

TABLE XIV.—*Showing the variation in the length of the egg stage as recorded in Table XII.*

Eggs.	Days.	Eggs.	Days.
27	8	96	13
51	9	15	14
181	10	2	15
209	11	0	16
131	12	8	17

FIRST BROOD OF LARVÆ.

As has been already stated, a number of the first-brood larvæ do not transform with the rest of the brood, but cocoon for the winter and hibernate with second-brood larvæ.

In rearing the codling-moth larvæ to obtain the time spent in feeding and the life cycle of the first generation, apples were used upon which several eggs had been deposited, in order to insure some of the larvæ living.

A number of the larvæ transformed within the half-dried apples and consequently only partial records can be given concerning them.

Time of hatching.—The first larvæ in the rearing cages appeared May 13 but these did not come from eggs deposited by the earliest moths on account of insufficient numbers of the latter.

It is very probable that the earliest larvæ appeared in the field from about April 20 to 25 if the time of emergence of the earliest moths, from March 30 to 31, is taken into consideration. As no effort was made to secure data as to when the latest larvæ hatched in the rearing cages this can not be given, but the latest hatching larvæ of the first brood probably appeared from about July 1 to 10, considering the time when the last moths emerged.

Number of larvæ developing in one apple.—In practically all of the rearing work to obtain a record of the time of feeding of the larvæ apples were used upon which a number of eggs had been deposited. In some instances as many as 20 eggs were laid on one apple but in no instance did a large number of larvæ mature. An examination of Table XV shows that usually one larva left the fruit, two larvæ left the apple in five instances, and three larvæ in one instance. In apples Nos. 11, 12, 13, 14, 15, and 16 a number of larvæ transformed, the number varying from 2 to 5. This seems to have been unusual according to the writings of other authors and was undoubtedly abnormal.

Period of feeding of larvæ in fruit.—In Table XV is recorded the feeding period of 46 larvæ which entered 16 apples, of which 27 left the apples, the rest remaining in the fruit; 31 larvæ transformed, 13 wintered, and 2 died. Of this number 25 transformed in the fruit, and 9 spun their cocoons, evidently intending to winter in the dried and shrunken apples.

TABLE XV.—*Larvæ of first brood. Feeding period of transforming and wintering larvæ; length of life cycle of first generation.*

Number of apple.	Larvæ entered apple. Date.	Larvæ entered apple. Number of larvæ.	Larvæ left fruit. Date.	Larvæ left fruit. Number of larvæ.	Time spent in fruit.	Larvæ spun cocoons. Locality.	Larvæ spun cocoons. Number of larvæ.	Larvæ pupated. Locality.	Larvæ pupated. Number of larvæ.	Adults emerged. Date.	Adults emerged. Number of larvæ.	Length of pupal stage.	Total time spent in cocoons.	Theoretical length of life cycle.
					Days.							Days.	Days.	
										July 8	1	......	......	75.4
1	May 9	4	June 11	1	33	In apple.	....	In apple.	....	July 10	1	......	......	77.4
										July 16	1	......	......	83.4
										July 20	1	......	......	87.4
2	...do....	2	June 13	1	35	...do.....	....	...do.....	....	July 8	1	......	......	75.4
			June 19	1	41	...do.....	....	...do.....	....	July 20	1	......	......	87.4
3	...do.....	2	June 9	2	31	...do.....	....	....	....	(1)	....	......	......	......
4	...do.....	1	...do.....	1	31	...do.....	....	In apple.	....	July 22	1	......	......	89.4
5	May 11	1	June 22	1	42	...do.....	....	....	....	(1)	....	......	......	......
6	May 13	2	July 1	2	49	...do.....	....	In apple.	....	July 25	1	......	......	88.4
										(2)	....	......	......	......
7	...do....	2	July 5	2	53	...do.....	....	...do.....	....	July 25	1	......	......	......
										(2)	....	......	......	......
										July 8	1	......	......	64.4
										July 11	1	......	......	67.4
8	May 18	5	June 19	1	32	...do.....	....	...do.....	....	July 19	1	......	......	75.4
										Aug. 3	1	......	......	90.4
										Aug. 14	1	......	......	101.4
										July 16	1	......	......	74.4
9	...do.....	4	June 22	1	35	...do.....	....	...do.....	....	July 17	1	......	......	75.4
										July 19	2	......	......	77.4
								..do.....	....	July 10	1	......	......	67.4
10	May 19	3	June 9	2	29	...do.....	....	..do.....	....	Aug. 3	1	......	......	91.4
								Aug. 11	1	Died....	....	......	......	......
										July 8	2	......	......	65.4
11	...do.....	5	June 22	1	34	...do.....	....	In apple.	....	July 10	1	......	......	67.4
										July 19	1	......	......	76.4
										July 11	1	......	......	68.4
12	May 28	3	June 30	1	33	July 1	1	July 1	1	July 10	1	9	9	58.4
			July 3	1	36	July 8	1	....	....	(3)	....	......	......	......
13	May 29	3	July 1	1	33	July 8	1	July 28	1	Aug. 19	1	22	42	97.4
			July 2	1	34	July 22	1	....	....	(3)	....	......	......	......
14	June 1	3	July 1	3	30	July 2	2	July 22	2	Aug. 5	2	14	34	80.4
15	...do.....	4	June 30	1	29	July 3	1	....	....	(3)	....	......	......	......
			July 1	1	30	July 8	1							
16	...do.....	2	July 2	2	31	..do.....	1	July 14	1	July 28	1	14	20	72.4
						July 12	1	July 22	1	Aug. 15	1	24	34	90.4

[1] Wintered as larvæ. [2] One wintered as larva. [3] Two wintered as larvæ.

In Table XVI a summary is given of the time spent in feeding by the larvæ as shown in Table XV.

TABLE XVI.—*Feeding period of larvæ of first brood.*

Observations.	Time spent in fruit.
	Days.
Average..........	38.1
Maximum........	53
Minimum........	29

Larval life in the cocoon.—Individual records were kept upon the time of cocooning, time of pupation, and emergence of the moths on 141 larvæ. (See Tables XVIII and XIX.) Under this heading would be placed the post-larval stage or the period between the first spinning of the cocoon and the time of pupation. The variations in the length of larval life in the cocoon are given in Table XVII.

TABLE XVII.—*Larvæ of the first brood—Variations in the length of the larval life in the cocoon.*

Number of larvæ.	Post-larval stage.	Number of larvæ.	Post-larval stage.	Number of larvæ.	Post-larval stage.	Number of larvæ.	Post-larval stage.
	Days.		*Days.*		*Days.*		*Days.*
3	2	1	10	2	21	1	31
2	3	3	11	3	22	1	36
12	4	3	13	3	23	1	39
11	5	3	16	2	25	1	39
38	6	4	17	1	26	1	40
7	7	2	18	2	27	1	41
4	8	1	19	4	29	1	50
12	9	1	20	3	30		

From Table XVII it will be seen that the average larval life in the cocoon was 11.7 days, the maximum 50 and the minimum 2 days. The average post-larval stage is considerably longer than given by either Mr. Jenne[1] in Arkansas in 1908 or by Mr. Hammar[2] in Pennsylvania in 1909, in their studies of the codling moth. The former obtained an average of 7.2 days, a maximum of 19 days, and a minimum of 3 days, while the latter obtained an average of 7.09 days, a maximum of 19 days, and a minimum of 3 days.

FIRST BROOD OF PUPÆ.

Time of pupation.—The first pupæ observed in the field were collected from under the bands on June 6 and from then on weekly to August 15. The first pupa observed in the cages was on June 25 and the last on August 20. Pupæ appeared in maximum numbers in the cages throughout the month of July. Considering the date of the emergence of the last moth on September 22 and subtracting the average length of the pupal stage, the date of the last larva pupating must have been about September 3.

Length of the first-brood pupal stage.—The larvæ upon which the pupal records are based were collected from banded trees in 1910. One collection was made June 10 of 46 larvæ and one June 20 of 95 larvæ, making a total of 141. In the first collections 11 larvæ were males and 35 females and in the second 27 individuals were males and 68 females. The sex of the larvæ was determined in the same manner as was that of the overwintering larvæ. (See p. 122.)

Table XVIII shows a detailed record of the 38 male larvæ which had an average pupal stage of 19.5 days; Table XIX shows a detailed record of the 102 female larvæ which had an average pupal stage of 18.8 days. From records of the overwintering larvæ and similar records for 1911 it was apparent that female larvæ required a longer pupal period. The above record seems to contradict the other records as 68 female larvæ, or 66 per cent of the total number of

[1] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part I. [2] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part VI.

females, were collected on June 30, the second collection, while 27 male larvæ, or 71 per cent of the total number of males, were taken on the second collection. It is evident therefore that a larger percentage of the total number of males was influenced by a higher mean temperature (on account of later collection in June) than females, which would naturally lead one to expect a shorter average pupal stage for the males in comparison with that of the females. Possibly a few individuals with a long pupal stage in the male series of 38 individuals caused a greater influence on the average length of the stage than the same number of individuals in the female series of 103 larvæ would do.

The average length of the pupal stage of all the larvæ was 19.04 days, the maximum 55 and the minimum 11 days. (See Table XX.) A summary of Tables XVIII and XIX is given in Table XX, showing the variations observed in the length of the stages during the entire period when pupæ were found.

TABLE XVIII.—*Pupæ of the first brood—Length of the pupal and cocoon periods of 38 male larvæ collected in 1910 on banded trees.*

No.	Date— Spun cocoon.	Date— Pupated.	Date— Emerged.	Length of pupal stage.	Length of cocoon stage.	No.	Date— Spun cocoon.	Date— Pupated.	Date— Emerged.	Length of pupal stage.	Length of cocoon stage.
				Days.	*Days.*					*Days.*	*Days.*
1	June 21	June 25	July 11	16	20	20	July 1	July 7	July 22	15	21
2	...do.....	June 27	July 14	17	23	21	...do.....	...do.....	July 20	13	19
3	...do.....	June 25	July 17	22	26	22	....	Aug. 9	Aug. 28	19	......
4	...do.....	June 27	...do.....	20	26	23	July 1	July 7	July 23	16	22
5	...do.....	...do.....	...do.....	20	26	24	...do.....	Aug. 1	Sept. 2	32	63
6	June 22	July 1	July 19	18	27	25	...do.....	July 5	July 20	15	19
7	...do.....	July 9	July 27	18	25	26	...do.....	July 23	Aug. 16	24	46
8	...do.....	July 19	Aug. 9	21	48	27	...do.....	Aug. 10	Sept. 4	25	65
9	June 24	June 30	July 17	17	23	28	...do.....	July 27	Aug. 15	19	55
10	...do.....	June 20	Aug. 10	21	47	29	...do.....	July 7	July 21	14	20
11	...do.....	July 12	Aug. 1	20	38	30	...do.....	July 28	Aug. 25	28	55
12	July 1	July 30	Aug. 24	25	54	31	...do.....	July 7	July 20	13	19
13	...do.....	July 24	Aug. 13	20	43	32	July 2	July 9	July 27	18	25
14	...do.....	...do.....	Aug. 16	23	46	33	...do.....	July 8	July 24	16	22
15	...do.....	July 19	Aug. 10	22	40	34	...do.....	July 7	...do.....	17	22
16	...do.....	July 5	July 20	15	19	35	...do.....	Aug. 1	Sept. 1	31	61
17	...do.....	July 7	July 23	16	22	36	July 4	July 14	Aug. 3	20	30
18	...do.....	...do.....	July 27	20	26	37	July 11	July 15	...do.....	19	23
19	....	...do.....	July 24	17	......	38	July 12	July 16	Aug. 7	22	26

TABLE XIX.—*Pupæ of the first brood. Length of the pupal and cocoon periods of 103 female larvæ collected on banded trees, 1910.*

No.	Date— Spun cocoon.	Date— Pupated.	Date— Emerged.	Length of pupal stage.	Length of cocoon stage.	No.	Date— Spun cocoon.	Date— Pupated.	Date— Emerged.	Length of pupal stage.	Length of cocoon stage.
				Days.	*Days.*					*Days.*	*Days.*
1	June 21	June 25	July 13	18	22	53	July 1	July 7	July 21	14	20
2	...do.....	June 27	July 15	18	24	54	...do.....	July 9	July 23	14	22
3	...do.....	...do.....	July 17	20	26	55	...do.....	July 7	July 24	17	23
4	...do.....	June 26	July 15	19	24	56	...do.....	Aug. 20	Sept. 18	29	79
5	....	June 25	July 17	22		57	...do.....	July 7	July 23	16	22
6	....	June 30	Aug. 24	55	......	58	...do.....	...do.....	July 21	14	20
7	June 21	June 25	July 14	19	23	59	...do.....	...do.....	July 20	13	19
8	...do.....	June 30	July 18	18	27	60	...do.....	July 10	July 27	17	26
9	...do.....	June 27	July 17	20	26	61	...do.....	July 8	July 24	16	23
10	...do.....	...do.....	July 15	18	24	62	...do.....	July 7	July 20	13	19
11	...do.....	...do.....	July 17	20	26	63	...do.....	July 14	Aug. 1	18	31
12	...do.....	July 11	July 27	16	36	64	...do.....	July 18	Aug. 7	20	37
13	...do.....	June 27	July 17	20	26	65	...do.....	July 7	July 21	14	20
14	...do.....	June 25	July 13	18	22	66	...do.....	July 17	Aug. 7	21	37
15	...do.....	June 27	July 17	20	26	67	...do.....	July 7	July 23	16	22
16	...do.....	Aug. 1	Aug. 31	30	71	68	...do.....	...do.....	July 21	14	20
17	...do.....	June 30	July 18	18	27	69	...do.....	July 10	July 28	18	27
18	...do.....	...do.....	...do.....	18	27	70	...do.....	July 17	Aug. 6	20	36
19	...do.....	July 21	Aug. 15	25	55	71	...do.....	July 12	July 31	19	30
20	...do.....	June 30	July 17	17	26	72	...do.....	July 23	Aug. 19	27	49
21	...do.....	June 27	July 15	18	24	73	...do.....	...do.....	Aug. 16	24	46
22	...do.....	...do.....	July 17	20	26	74	...do.....	July 7	July 24	17	23
23	...do.....	July 2	July 20	18	29	75	...do.....	July 22	Aug. 15	24	45
24	...do.....	June 30	July 17	17	26	76	...do.....	July 3	July 22	19	21
25	June 22	...do.....	July 18	18	26	77	...do.....	July 14	Aug. 3	20	33
26	....	June 29	...do.....	19	......	78	...do.....	July 3	July 20	17	19
27	June 22	June 25	July 13	18	21	79	...do.....	July 10	July 21	11	20
28	...do.....	July 1	July 20	19	28	80	July 2	July 6	...do.....	15	19
29	...do.....	July 3	...do.....	17	28	81	...do.....	July 9	July 25	16	23
30	...do.....	June 30	...do.....	20	28	82	...do.....	July 25	Aug. 18	24	47
31	...do.....	June 27	July 17	20	25	83	...do.....	July 7	July 21	14	19
32	...do.....	...do.....	...do.....	20	25	84	...do.....	...do.....	July 20	13	18
33	June 23	...do.....	...do.....	20	24	85	...do.....	...do.....	July 21	14	19
34	June 24	July 15	Aug. 3	19	40	86	...do.....	July 6	...do.....	15	19
35	...do.....	July 1	July 18	17	24	87	...do.....	July 7	July 20	13	18
36	July 1	July 7	July 21	14	20	88	...do.....	Aug. 1	Sept. 4	34	64
37	...do.....	...do.....	...do.....	14	20	89	...do.....	July 11	July 28	17	26
38	...do.....	July 26	Aug. 21	26	51	90	...do.....	July 18	Aug. 9	22	38
39	...do.....	July 8	July 24	16	23	91	....	July 26	Aug. 18	23	....
40	...do.....	July 30	Aug. 24	25	54	92	July 2	July 7	July 21	14	19
41	...do.....	July 4	July 20	16	19	93	...do.....	Aug. 10	Sept. 10	31	70
42	...do.....	July 8	July 23	15	22	94	...do.....	July 8	July 24	16	22
43	...do.....	...do.....	July 25	17	24	95	...do.....	July 31	Aug. 29	29	58
44	....	July 18	Aug. 7	20	......	96	...do.....	July 8	July 24	16	22
45	July 1	...do.....	Aug. 6	19	36	97	...do.....	July 7	July 21	14	19
46	...do.....	July 7	July 20	13	19	98	...do.....	July 4	July 20	16	18
47	...do.....	July 9	July 28	19	27	99	....	July 7	July 24	17	....
48	...do.....	July 7	July 21	14	20	100	July 2	...do.....	July 23	16	21
49	...do.....	...do.....	...do.....	14	20	101	July 3	July 22	Aug. 14	23	42
50	...do.....	July 14	Aug. 1	18	31	102	...do.....	July 8	July 24	16	21
51	...do.....	July 10	July 27	17	26	103	July 7	Aug. 4	Sept. 2	29	57
52	...do.....	July 8	July 24	16	23						

TABLE XX.—*Pupæ of the first brood; length of pupal period. Summary of Tables XVIII and XIX.*

Observations.	Pupal period.
	Days.
Average..........	19.04
Maximum........	55
Minimum........	11

TABLE XXI.—*Pupæ of the first brood; variation in length of pupal stage. Summary of Tables XVIII and XIX.*

Number of pupæ.	Pupal stage.	Number of pupæ.	Pupal stage.	Number of pupæ.	Pupal stage.	Number of pupæ.	Pupal stage.
	Days.		*Days.*		*Days.*		*Days.*
1	11	3	23	0	35	0	47
0	12	4	24	0	36	0	48
7	13	4	25	0	37	0	49
14	14	1	26	0	38	0	50
6	15	1	27	0	39	0	51
17	16	1	28	0	40	0	52
16	17	3	29	0	41	0	53
17	18	1	30	0	42	0	54
12	19	2	31	0	43	0	55
20	20	1	32	0	44		
3	21	0	33	0	45		
5	22	1	34	0	46		

FIRST BROOD OF MOTHS.

Time of emergence.—On July 8 the earliest first-brood moths appeared from band material collected June 7, while the last moth

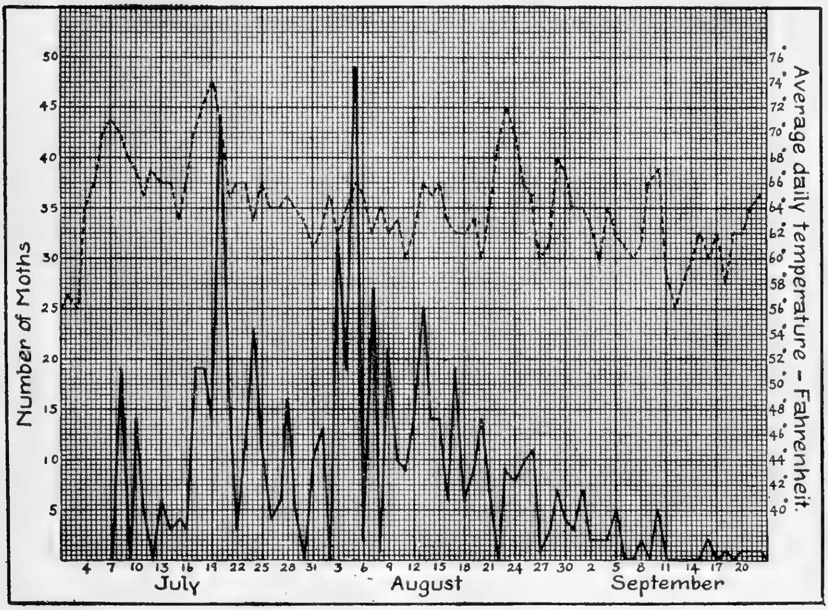

FIG. 30.—Diagram showing emergence of first-brood moths for 1910. (Original.)

of the spring brood emerged June 9. The gap between the last spring moths and the earliest first-brood moths was therefore about one month.

As shown in figure 30 and Table XXII moths emerged in large numbers and in small numbers intermittently until September 22. No absolute maximum could be determined, but the majority of the moths emerged during a period embracing the latter half of July and the first half of August. As shown in figure 30, the daily mean tempera-

ture seems to have influenced emergence to some extent, especially during the early part. After August 18, when most of the moths had already emerged, no conclusions could be drawn regarding the influence of temperature conditions.

The emergence curves of both spring and first-brood moths, as recorded at San Jose, are very much at variance with those of Mr. Hammar[1] at North East, Pa., who obtained more gradual maximums and minimums and not such sudden rises and falls as are recorded in this paper. The warmer nights in the Eastern States undoubtedly bring about this set of conditions.

TABLE XXII.—*Emergence of moths of the first brood from material collected from banded trees.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 8	19	July 26	4	Aug. 13	25	Aug. 30	4
July 10	14	July 27	6	Aug. 14	14	Aug. 31	3
July 11	5	July 28	16	Aug. 15	14	Sept. 1	7
July 13	6	July 29	5	Aug. 16	6	Sept. 2	2
July 14	3	July 31	10	Aug. 17	19	Sept. 3	2
July 15	4	Aug. 1	13	Aug. 18	6	Sept. 4	2
July 16	3	Aug. 3	32	Aug. 19	8	Sept. 5	5
July 17	19	Aug. 4	19	Aug. 20	14	Sept. 8	2
July 18	19	Aug. 5	49	Aug. 21	7	Sept. 10	5
July 19	14	Aug. 6	2	Aug. 23	9	Sept. 16	2
July 20	44	Aug. 7	27	Aug. 24	8	Sept. 18	1
July 21	18	Aug. 8	1	Aug. 25	10	Sept. 20	1
July 22	3	Aug. 9	22	Aug. 26	11	Sept. 21	1
July 23	12	Aug. 10	10	Aug. 27	1	Sept. 22	1
July 24	23	Aug. 11	9	Aug. 28	3		
July 25	11	Aug. 12	14	Aug. 29	7		

Oviposition period.—No individual records for oviposition were kept except that 10 or 12 separate pairs were confined in mica chimneys to find out the total number of eggs a single moth would deposit. Unfortunately these notes were lost and also the data on the length of oviposition. It will be seen later from data on the length of the egg stage that eggs were obtained July 9, one day after the first moths emerged. This appears to be unusual and in all probability the first moths emerged before July 8, but were overlooked in the jars. General observations on the length of oviposition, while securing eggs in the cages made it evident that some moths deposited eggs for from 7 days up to 2 weeks.

LIFE CYCLE OF FIRST GENERATION.

As will be seen in Table XV, a number of larvæ were reared in apples and records kept until the moths emerged. This with the exception of the length of the egg stage and an addition of 3 days (time before oviposition) would give the life cycle, which is properly from egg to egg. The average length of the egg stage of the first

[1] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part VI.

generation being 12.4 days plus 3 days makes 15.4 days, to be added to each period where the larva was reared to a moth.

A summary of Table XV shows the following data:

TABLE XXIII.—*Summary of Table XV showing the theoretical life cycle of the first generation.*

Number of individuals.	Length of life cycle.	Number of individuals.	Length of life cycle.	Number of individuals.	Length of life cycle.	Number of individuals.	Length of life cycle.
	Days.		*Days.*		*Days.*		*Days.*
1........	72.4	1........	89.4	1........	74.4	1........	76.4
2........	90.4	2........	88.4	3........	77.4	1........	68.4
1........	58.4	4........	75.4	3........	67.4	1........	64.4
1........	97.4	1........	83.4	1........	91.4	1........	101.4
2........	80.4	2........	87.4	2........	65.4		

A summary of Table XXIII shows the average life cycle to be 78.62 days, the maximum 101.4 days, and the minimum 58.4 days. The average length of the egg stage, 12.4 days, added to the average feeding period of the larvæ, 38.1 days, added to 11.7 days, the average postlarval stage, added to 19.4 days, the average pupal stage, added to 3 days' time before oviposition, makes a total of 84.24 days, which is about 6 days more than was obtained by actual rearing records.

SECOND GENERATION.

SECOND BROOD OF EGGS.

Incubation period.—The same methods were used for obtaining eggs of the second generation as were practiced on the first generation, viz, placing moths in Riley cages in which apples were suspended by strings. Nearly all of the moths were utilized for this work throughout the emergence period, thus giving practically the true period of oviposition that would naturally obtain in the field. In this manner eggs were obtained from July 9 up to September 25, inclusive, a period of 78 days. Eggs were obtained in the cages the day after the emergence of the earliest first-brood moths, and three days after the last first-brood moth emerged. Moths emerged in such small numbers during the month of September that proper mating was hindered and consequently few eggs were deposited after the last moth emerged.

A record was kept of the second-brood eggs, as with the first-brood eggs, showing the length before the red ring appeared and before the black spot appeared, both of which indicate distinct periods, so that when eggs are obtained in the field they can be classed according to their age with some degree of accuracy.

In the cages eggs were obtained practically every day from July 9 to September 25, and in all a total of 1,861 eggs were kept under

observation, 1,748 of which hatched, or a total of 93 per cent. A complete record of the incubation periods of all the eggs is shown in Table XXIV.

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages.*

No. of apple.	Number of eggs.	Date of deposition.	Red ring. Date of appearance.	Red ring. Number of eggs.	Black spot. Date of appearance.	Black spot. Number of eggs.	Hatched. Date.	Hatched. Number of eggs.	Length of egg stage.
									Days.
1	2	July 9	July 12	2	July 18	2	July 19	2	10
2	4	...do....	...do....	4	...do....	4	...do....	4	10
3	7	July 10	...do....	7	...do....	7	...do....	7	9
4	2	July 11	July 13	2	...do.... July 19	1 1	July 20	2	9
5	4	...do....	...do....	4	...do....	4	...do....	4	9
6	1	...do....	...do....	1	...do....	1	July 21	1	10
7	1	July 12	...do....	1	...do....	1	July 20	1	8
8	4	...do....	July 14	3	...do....	3	...do.... July 21	2 1	8 9
9	6	...do....	...do....	6	...do....	6	July 20 July 21	3 3	8 9
10	10	...do....	...do....	10	...do....	8	July 20 July 21	3 5	8 9
11	2	...do....	...do....	2	...do....	2	July 20	2	8
12	6	July 13	July 15	6	July 20	6	July 21	6	8
13	2	...do....	...do....	1	...do....	2	...do....	2	8
14	1	...do....	...do....	1	...do....	1	...do....	1	8
15	3	...do....	...do....	3	...do....	3	...do....	3	8
16	5	...do....	...do....	5	...do....	5	...do....	5	8
17	2	July 14	...do....	2	...do....	2	...do....	2	7
18	3	...do....	July 16	2	July 21	3	...do....	2	7
19	3	...do....	...do....	3	July 20	1	...do....	3	7
20	3	...do....	...do....	2	...do....	1	...do....	3	7
21	2	...do....	...do....	2	July 21	2	...do....	2	7
22	2	...do....	...do....	2	...do....	2	...do....	2	7
23	1	...do....	...do....	1	...do....	1	...do....	1	7
24	14	...do....	...do....	14	...do....	14	...do....	14	7
25	1	July 15	July 17	1	...do....	1	July 23	1	8
26	1	July 16	July 18	1	July 22	1	...do....	1	7
27	3	July 17	...do.... July 19	1 2	July 23	3	July 24 July 26	1 2	7 9
28	5	...do....	...do....	5	...do....	5	July 24 July 26	3 2	7 9
29	3	July 19	July 20	2	July 24 July 25 July 26	1 1 1	July 27	3	8
30	5	July 21	July 22 July 23	1 3	July 28 July 29	2 3	July 29 July 30 July 31	1 3 1	8 9 10
31	7	...do....	...do.... July 24	5 2	...do....	7	...do.... July 31	3 4	9 10
32	11	...do....	July 23 July 24	8 3	...do....	11	...do....	11	10
33	6	July 22	...do....	6	July 31	6	Aug. 1	6	10
34	1	...do....	...do....	1	...do....	1	...do....	1	10
35	1	...do....	...do....	1	...do....	1	...do....	1	10
36	3	...do....	...do....	3	...do....	3	...do.... Aug. 2	2 1	10 11
37	10	...do....	...do....	10	...do....	10	Aug. 1 Aug. 2	6 4	10 11
38	2	...do....	...do....	2	...do....	1	Aug. 1	2	10
39	15	July 23	July 25	13	Aug. 1	15	Aug. 3	13	11
40	8	...do....	...do....	8	...do....	8	...do....	8	11
41	8	...do....	...do....	8	...do....	8	...do....	8	11
42	3	...do....	...do....	2	...do....	2	...do....	3	11
43	29	July 24	July 26 July 27	24 2	Aug. 2 Aug. 3	16 10	Aug. 4	26	11
44	14	...do....	July 26 Aug. 1	13 1	Aug. 2 Aug. 3	12 2	...do.... Aug. 5	12 2	11 12
45	14	...do....	July 26 July 28	8 6	Aug. 2 Aug. 3	2 1	Aug. 4 Aug. 5	1 2	11 12
46	21	...do....	July 26 July 28	17 4	Aug. 2 Aug. 3 Aug. 4	6 5 2	Aug. 4	9	11
47	17	July 25	...do....	13	Aug. 3 Aug. 4	5 12	Aug. 5 Aug. 6	8 7	11 12
48	8	...do....	...do....	6	Aug. 3 Aug. 4	2 6	Aug. 5 Aug. 6	2 2	11 12

Table XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

Number of apple.	Number of eggs.	Date of deposition.	Red ring. Date of appearance.	Red ring. Number of eggs.	Black spot. Date of appearance.	Black spot. Number of eggs.	Hatched. Date.	Hatched. Number of eggs.	Length of egg stage.
									Days.
49	23	July 25	July 28	15	Aug. 3	14	Aug. 5	11	11
					Aug. 4	9	Aug. 6	9	12
50	10	July 26	...do....	9	Aug. 3	3	Aug. 5	2	10
					Aug. 4	7	Aug. 6	6	11
51	31	...do....	...do....	28	Aug. 3	18	Aug. 5	9	10
					Aug. 4	13	Aug. 6	13	11
							Aug. 7	1	12
52	16	...do....	...do....	6	Aug. 4	7	Aug. 5	5	10
			July 29	8	Aug. 5	4	Aug. 7	11	11
53	11	...do....	July 28	4	Aug. 4	5	Aug. 5	5	10
			July 29	6	Aug. 5	1	Aug. 7	6	12
54	3	...do....	July 28	3	Aug. 4	1	Aug. 6	1	11
					Aug. 5	2	Aug. 7	2	12
55	4	...do....	...do....	2	...do....	3	...do....	3	12
56	10	...do....	...do....	6	Aug. 4	5	Aug. 5	3	10
					Aug. 5	2	Aug. 6	3	11
							Aug. 7	4	12
57	11	July 27	July 29	7	...do....	7	...do....	4	11
					Aug. 6	3	Aug. 8	3	12
							Aug. 9	3	13
58	2	...do....	Aug. 5	1	....	....	....	....	....
59	4	...do....	July 28	3	Aug. 5	3	Aug. 7	2	11
					Aug. 7	1	Aug. 8	1	12
							Aug. 10	1	14
60	7	...do....	...do....	6	Aug. 5	4	Aug. 7	6	11
					Aug. 6	2			
61	3	July 28	Aug. 1	1	Aug. 7	3	Aug. 9	3	12
62	9	...do....	...do....	4	Aug. 5	1	....	....	....
63	1	...do....	...do....	1	....	....	....	....	....
64	2	...do....	July 28	1	Aug. 7	2	Aug. 9	2	12
			Aug. 1	1					
65	2	July 29	...do....	2	...do....	2	...do....	2	11
66	14	July 30	...do....	2	Aug. 8	5	Aug. 10	12	11
			Aug. 2	6	Aug. 9	8	Aug. 11	1	12
			Aug. 5	4	Aug. 10	1			
67	6	...do....	Aug. 1	5	Aug. 8	2	Aug. 10	6	11
			Aug. 2	1	Aug. 9	4			
68	7	...do....	...do....	3	Aug. 8	7	...do....	7	11
			Aug. 3	1					
			Aug. 4	3					
69	9	July 31	Aug. 2	3	Aug. 9	9	Aug. 11	8	11
			Aug. 3	6			Aug. 12	1	12
70	7	...do....	Aug. 2	6	...do....	7	Aug. 11	7	11
71	20	...do....	...do....	8	...do....	20	...do....	19	11
			Aug. 3	12			Aug. 12	1	12
72	6	Aug. 1	...do....	5	Aug. 10	6	Aug. 11	1	10
							Aug. 12	5	11
73	4	...do....	...do....	2	...do....	3	...do....	1	11
			Aug. 4	1					
74	4	Aug. 2	...do....	1	....	....	....	....	....
			Aug. 5	3					
75	16	...do....	Aug. 4	12	Aug. 11	16	Aug. 13	16	11
			Aug. 5	4					
77	17	...do....	Aug. 4	6	...do....	17	Aug. 14	17	11
			Aug. 5	8					
78	18	Aug. 3	...do....	16	Aug. 12	12	...do....	14	11
			Aug. 6	2	...do....	6	Aug. 15	4	12
79	11	...do....	Aug. 5	4	...do....	8	Aug 14	7	11
			Aug. 6	1	Aug. 13	3	Aug. 15	4	12
80	9	...do....	Aug. 5	9	Aug. 12	3	Aug. 14	4	11
					Aug. 13	6	Aug. 15	4	12
81	4	Aug. 4	Aug. 6	4	Aug. 14	4	...do....	4	11
82	3	...do.....	...do.....	3	Aug. 13	3	...do.....	3	11
83	4	Aug. 5	...do.....	1	...do.....	3	Aug. 16	4	11
84	19	...do.....	Aug. 7	5	Aug. 14	19	...do.....	19	11
85	17	...do.....	...do.....	9	...do.....	14	...do.....	17	11
			Aug. 8	1	Aug. 15	1			
86	35	Aug. 6	...do.....	27	...do.....	24	...do.....	20	10
			Aug. 11	5			Aug. 17	14	11
87	2	...do.....	Aug. 8	2	...do.....	1	Aug. 16	1	10
					Aug. 16	1	Aug. 17	1	11
88	13	...do.....	...do.....	9	Aug. 15	10	Aug. 16	8	10
			Aug. 10	4	Aug. 16	3	Aug. 17	5	11

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

Number of apple.	Number of eggs.	Date of deposition.	Red ring. Date of appearance.	Red ring. Number of eggs.	Black spot. Date of appearance.	Black spot. Number of eggs.	Hatched. Date.	Hatched. Number of eggs.	Length of egg stage.
									Days.
89	46	Aug. 7	Aug. 9 Aug. 10 Aug. 12	8 27 9	Aug. 16	46	Aug. 17 Aug. 18	3 43	10 11
90	28	...do.....	Aug. 9 Aug. 10 Aug. 11	20 4 2	..do..... Aug. 17	24 4	Aug. 17 Aug. 18 Aug. 19	3 19 6	10 11 12
91	13	...do.....	Aug. 9 Aug. 10 Aug. 11	2 7 2	Aug. 16 Aug. 17	7 6	Aug. 18	13	11
92	3	...do.....	Aug. 10	1	..do..... Aug. 18	2 1	..do.....	2	11
93	24	Aug. 9	Aug. 11 Aug. 12	7 17	..do.....	24	Aug. 20	24	11
94	11	...do....	...do.....	9	Aug. 18 Aug. 19	8 5	..do	11	11
95	35	...do.....	...do.....	23	Aug. 18 Aug. 19	32 3	..do.....	35	11
96	6	...do.....	...do.....	3	Aug. 18	6	...do.....	6	11
97	10	...do.....	...do.....	8	...do.....	10	...do.....	10	11
98	4	Aug. 10	Aug. 13	4	Aug. 19	4	..do..... Aug. 21	2 2	10 11
99	4	...do.....	...do.....	2	...do.....	2	Aug. 20 Aug. 21	2 1	10 11
100	5	...do.....	...do.....	4	...do.....	5	Aug. 20 Aug. 21	1 4	10 11
101	17	...do.....	...do.....	7	...do.....	13	...do.....	14	11
102	5	Aug. 11	Aug. 14	2	Aug. 21	5	Aug. 22 Aug. 23	1 3	11 12
103	9	...do.....	...do.....	9	...do.....	9	Aug. 22 Aug. 23	3 5	11 12
104	8	...do.....	...do.....	5	...do.....	8	Aug. 22 Aug. 23	6 2	11 12
105	4	...do.....	...do.....	3	..do..... Aug. 22	2 2	Aug. 22 Aug. 23	2 2	11 12
107	4	Aug. 12	Aug. 15	4	Aug. 21 Aug. 22	3 1	..do.....	3	11
108	17	...do.....	...do.....	10	Aug. 21	17	...do.....	17	11
109	5	...do.....	Aug. 16	4	...do.....	5	...do.....	5	11
110	8	Aug. 13	...do.....	6	Aug. 22 Aug. 23	5 3	..do.....	8	10
111	2	...do.....	Aug. 15	1	Aug. 22	2	Aug. 24	2	11
112	6	...do.....	Aug. 17	6	..do..... Aug. 23	4 2	...do..... Aug. 25	5 1	11 12
113	27	Aug. 14	...do.....	27	...do.....	27	Aug. 24 Aug. 25	19 8	10 11
114	30	...do.....	...do.....	30	...do.....	30	Aug. 24 Aug. 25	22 8	10 11
115	28	...do.....	...do.....	28	...do.....	28	Aug. 24 Aug. 25	22 6	10 11
116	49	Aug. 15	...do.....	49	Aug. 24	49	...do.....	48	10
117	51	...do.....	...do.....	51	...do.....	51	...do.....	51	10
118	37	...do.....	...do.....	37	...do.....	37	..do..... Aug. 26	34 3	10 11
119	81	Aug. 16	Aug. 18 Aug. 19	26 55	...do..... Aug. 25	19 62	...do..... Aug. 27	56 25	10 11
120	60	...do.....	Aug. 18 Aug. 19	30 30	Aug. 24 Aug. 25	29 31	Aug. 26 Aug. 27	30 30	10 11
121	46	. .do.....	Aug. 18 Aug. 19	20 26	Aug. 24 Aug. 25	40 6	Aug. 26 Aug. 27	44 2	10 11
122	11	Aug. 17	..do..... Aug. 21	5 6	...do..... Aug. 26	5 5	...do..... Aug. 28	7 4	10 11
123	23	...do.....	Aug. 19 Aug. 21	10 12	Aug. 25 Aug. 26	11 12	Aug. 27 Aug. 28	15 8	10 11
124	19	...do.....	Aug. 19 Aug. 21	8 11	Aug. 25 Aug. 26	8 11	Aug. 27 Aug. 28	12 7	10 11
125	3	Aug. 18	Aug. 20 Aug. 21	1 2	...do..... Aug. 27	2 1	Aug. 30	3	12
126	4	...do.....	Aug. 20 Aug. 21	2 2	Aug. 26 Aug. 27	1 3	..do.....	4	12
127	4	...do.....	Aug. 20 Aug. 21	2 2	...do..... Aug. 28	3 1	Aug. 29 Aug. 30	2 1	11 12
128	11	Aug. 19	...do.....	11	Aug. 27 Aug. 28	9 2	..do.....	11	11

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

Number of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date.	Number of eggs.	
									Days.
129	12	Aug. 20	Aug. 21 Aug. 22 Aug. 23 Aug. 24	3 3 2 1	Aug. 27 Aug. 28 Aug. 29	3 1 8	Aug. 30 Aug. 31	7 5	10 11
130	16	...do.....	Aug. 23 Aug. 24	5 3	Aug. 28 Aug. 29	2 14	Aug. 30 Aug. 31	10 6	10 11
131	8	Aug. 21	..do..... Aug. 25	1 2	Aug. 30	8	Sept. 1	8	11
132	7	...do.....	Aug. 24	2	...do.....	7	...do.....	7	11
133	9	Aug. 22	...do.....	5	..do..... Aug. 31	7 1	..do.....	9	10
134	5	...do.....	...do.....	3	Aug. 30	5	...do.....	5	10
135	2	...do.....	...do.....	1	Aug. 31	1	Sept. 2	1	11
136	7	Aug. 23	Aug. 25	4	..do..... Sept. 1	4 3	..do.....	5	10
137	19	...do.....	Aug. 24 Aug. 26	4 8	..do.....	19	..do..... Sept. 3	15 4	10 11
138	8	...do.....	Aug. 25 Aug. 26	3 3	..do.....	8	Sept. 2 Sept. 3 Sept. 4	3 3 2	10 11 12
139	9	Aug. 24	...do.....	3	Sept. 2 Sept. 3	2 2	..do..... Sept. 5 Sept. 6	7 1 1	11 12 13
140	11	...do.....	...do.....	10	Sept. 2 Sept. 3	9 2	Sept. 4 Sept. 5	9 2	11 12
141	3	...do.....	...do.....	1	Sept. 2	3	Sept. 4	3	11
142	6	Aug. 25	Aug. 28	4	Sept. 3 Sept. 4	4 2	Sept. 5 Sept. 6	2 2	11 12
143	2	...do.....	...do.....	2	Sept. 3	2	Sept. 5 Sept. 6	1 1	11 12
144	4	...do.....	...do.....	3	..do..... Sept. 4	2 1	..do.....	3	12
145	4	Aug. 26	Aug. 29	1	Sept. 5 Sept. 6	2 2	...do..... Sept. 7	3 1	11 12
146	21	...do.....	...do.....	10	Sept. 5 Sept. 6	17 4	..do.....	21	12
147	19	...do.....	...do.....	8	Sept. 5	19	...do.....	17	12
148	11	Aug. 27	Aug. 30	2	Sept. 6	11	Sept. 8	11	12
149	6	...do.....	...do.....	3	...do.....	6	...do.....	6	12
150	5	Aug. 28	...do.....	2	Sept. 7	5	Sept. 9	5	12
151	4	...do.....	...do.....	2	...do.....	4	...do.....	4	12
152	12	Aug. 29	Aug. 31	3	Sept. 8 Sept. 9	10 2	Sept. 10 Sept. 11	9 3	12 12
153	8	...do.....	...do.....	7	Sept. 8 Sept. 9	3 1	Sept 10	3	12
154	23	Aug. 30	Sept. 2	19	...do.... Sept. 10	2 21	Sept. 11 Sept. 12	12 9	12 13
155	4	...do.....	...do.....	4	Sept. 9 Sept. 10	1 3	Sept. 11 Sept. 12	2 2	12 13
156	14	...do.....	...do.....	11	Sept. 9 Sept. 10	6 8	Sept. 11 Sept. 12 Sept. 13	11 1 2	12 13 14
157	2	Aug. 31	Sept. 3 Sept. 4	1 1	..do.....	2	Sept. 12	2	12
158	2	...do.....	...do.....	12	Sept. 11	2	...do.....	1	12
159	2	Sept. 2	Sept. 6	2	Sept. 13	2	Sept. 16	2	14
160	8	...do.....	...do.....	7	..do..... Sept. 14	4 2	Sept. 15 Sept. 16	2 4	13 14
162	11	...do.....	...do.....	7	Sept. 13	11	...do.....	11	14
163	8	Sept. 3	Sept. 7	8	Sept. 14 Sept. 15	6 2	...do .... Sept. 17	6 2	13 14
164	5	...do.....	...do.....	5	Sept. 14	5	Sept. 16 Sept. 17	2 3	13 14
165	7	...do.....	...do.....	7	...do.....	7	Sept. 16 Sept. 17	2 5	13 14
166	5	...do.....	...do.....	5	Sept. 15	5	..do..... Sept. 18	4 1	13 14
167	3	Sept. 4	Sept. 8	3	...do.....	5	Sept. 17 Sept. 18	2 1	13 14
168	3	Sept. 5	Sept. 9	1	Sept. 17	2	Sept. 19	2	14
169	2	...do.....	...do.....	2	...do.....	2	...do.....	2	14
170	1	Sept. 7	Sept. 10	1	Sept. 19	1	Sept. 22	1	15
171	11	Sept. 9	Sept. 11	7	Sept. 21	11	Sept. 24	11	15
172	5	...do.....	...do.....	1	...do.....	2	...do.....	2	15
173	4	...do.....	Sept. 13	2	...do.....	2	...do.....	2	15

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

Number of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date.	Number of eggs.	
									Days.
174	8	Sept. 10	Sept. 13	8	Sept. 22	3	Sept. 25	2	15
					Sept. 23	2	Sept. 27	3	17
175	3	...do.....	...do.....	3	Sept. 22	2	Sept. 25	2	15
					Sept. 23	1	Sept. 26	1	16
176	13	...do.....	...do.....	13	Sept. 22	11	Sept. 25	10	15
					Sept. 23	2	Sept. 26	3	16
178	12	Sept. 11	Sept. 15	6	...do.....	3	Sept. 25	1	14
			Sept. 17	3	Sept. 24	9	Sept. 26	11	15
179	1	Sept. 12	Sept. 15	1	Sept. 26	1	Sept. 27	1	15
180	5	Sept. 14	Sept. 18	2	...do.....	5	Sept. 29	5	15
181	6	...do.....	...do.....	6	...do.....	5	...do.....	6	15
					Sept. 27	1			
182	13	...do.....	...do.....	7	Sept. 26	13	...do.....	13	15
183	1	Sept. 15	Sept. 19	1	Sept. 27	1	Sept. 30	1	15
184	6	Sept. 17	Sept. 20	6	Sept. 30	6	Oct. 2	6	15
185	3	...do.....	...do.....	5	...do.....	7	...do.....	7	15
186	3	Sept. 18	Sept. 22	2	Oct. 1	3	Oct. 3	3	15
187	3	...do.....	...do.....	3	...do.....	2	...do.....	2	15
188	3	Sept. 21	Sept. 24	3	Oct. 4	2	Oct. 6	2	15
189	3	Sept. 22	Sept. 25	3	Oct. 6	3	Oct. 8	3	16

The length of the egg stage ranged from 7 to 17 days, with an average of 10.92 days. Very little difference in the length of the stage is shown by Table XXIV for the 78 days or period of ovipositing by the first-brood moths. The red ring appeared from 2 to 3 days after deposition usually, the black spot from 6 to 10 days.

TABLE XXV.—*Incubation period of second-brood eggs. Summary of Table XXIV.*

Observation.	For appearance of red ring.	For appearance of black spot.	For incubation.
	Days.	*Days.*	*Days.*
Average..........	2.64	9.24	10.92
Maximum........	9	15	17
Minimum.........	1	5	7

SECOND BROOD OF LARVÆ.

Feeding period.—As mentioned under the egg stage, eggs were obtained from July 9 to September 25, a period of 78 days, and were hatching from about July 19 to October 8. The feeding periods were observed on a number of these at various intervals and developed normally and spun cocoons in the rearing cages in which they passed the winter. The details of these records are given in Table XXVI.

TABLE XXVI.—*Larvæ of second brood. Period of feeding of larvæ in rearing cages.*

No. of larva.	Date of— Hatching.	Date of— Leaving fruit.	Days of feeding.	No. of larva.	Date of— Hatching.	Date of— Leaving fruit.	Days of feeding.
1	July 20	Aug. 29	40	43	Aug. 20	Sept. 20	31
2	July 21	...do.....	39	44	...do.....	Sept. 25	36
3	...do.....	...do.....	39	45	...do.....	Sept. 24	35
4	...do.....	Sept. 11	52	46	...do.....	Sept. 29	40
5	...do.....	Sept. 13	54	47	...do.....	Sept. 28	39
6	...do.....	Aug. 30	40	48	...do.....	Sept. 23	34
7	...do.....	Aug. 31	41	49	Aug. 21	Oct. 7	48
8	...do.....	...do.....	41	50	Aug. 22	Oct. 18	57
9	...do.....	Sept. 2	43	51	...do.....	Sept. 25	34
10	...do.....	Aug. 31	41	52	...do.....	Sept. 29	38
11	July 26	Sept. 17	53	53	Aug. 23	Sept. 28	36
12	July 29	Sept. 5	38	54	...do.....	Sept. 30	38
13	July 31	Sept. 28	59	55	...do.....	Sept. 26	34
14	Aug. 10	Sept. 15	36	56	...do.....	Oct. 6	44
15	...do.....	Sept. 21	42	57	Aug. 24	Sept. 26	35
16	Aug. 11	Sept. 15	35	58	...do.....	Sept. 25	34
17	Aug. 12	Sept. 20	39	59	...do.....	Oct. 12	49
18	Aug. 11	Sept. 10	30	60	...do.....	Oct. 15	52
19	Aug. 12	Sept. 13	32	61	Aug. 25	Oct. 10	46
20	Aug. 13	Sept. 26	44	62	...do.....	Oct. 7	43
21	Aug. 14	Sept. 13	30	63	...do.....	Oct. 6	42
22	Aug. 15	Sept. 17	33	64	Aug. 27	Sept. 27	31
23	Aug. 14	Sept. 15	32	65	...do.....	Oct. 6	40
24	Aug. 15	Sept. 25	41	66	Aug. 30	Oct. 7	38
25	...do.....	Sept. 28	44	67	...do.....	Sept. 29	30
26	Aug. 14	Sept. 21	38	68	...do.....	Oct. 16	47
27	Aug. 15	Sept. 19	35	69	...do.....	Oct. 7	38
28	...do.....	Sept. 18	34	70	...do.....	Oct. 21	52
29	Aug. 16	Sept. 30	45	71	Sept. 1	Oct. 9	38
30	...do.....	Sept. 19	34	72	...do.....	Oct. 13	42
31	...do.....	...do.....	34	73	Sept. 2	Oct. 16	44
32	Aug. 17	Oct. 1	45	74	...do.....	Oct. 18	46
33	...do.....	Sept. 25	39	75	Sept. 3	Oct. 19	46
34	Aug. 18	Sept. 30	43	76	Sept. 4	...do.....	45
35	Aug. 17	Sept. 24	38	77	...do.....	Oct. 5	31
36	Aug. 18	Sept. 27	40	78	Sept. 7	Oct. 19	42
37	...do.....	Sept. 22	35	79	Sept. 10	Oct. 18	38
38	...do.....	Sept. 24	37	80	Sept. 12	Oct. 22	40
39	Aug. 20	Oct. 5	48	81	Sept. 16	Oct. 21	35
40	...do.....	Sept. 26	37	82	Sept. 17	Oct. 24	37
41	...do.....	Sept. 30	41	83	Sept. 25	Nov. 4	40
42	...do.....	Oct. 3	44				

TABLE XXVII.—*Feeding period of larvæ of the second brood. Summary of Table XXVI.*

Observations.	Feeding periods.
Average..........	40
Maximum........	59
Minimum.........	30

The feeding periods of the larvæ under observation ranged from 30 to 59 days, with an average of 40 days. It will be seen by comparing the records of the first-brood larvæ with these that practically no difference existed between the length of the feeding periods of the first and the second-brood larvæ.

Time of leaving the fruit for winter.—The earliest second-brood larvæ to leave the fruit in the cages to hibernate did so on August 29, but were probably one or two weeks earlier in the field. The last larvæ in the cages to leave the fruit did so on November 4, which is

quite close to the time the last larvæ had matured in the field according to the band record.

The senior author observed a half-grown larva feeding in an apple in a tree November 30, 1911, and it is possible larvæ could live much longer in the field if the fruit was not picked or would fall from the trees.

REVIEW OF LIFE-HISTORY WORK OF 1910.

During 1910 the life-history work of both broods of the codling moth was carefully worked out and results of these observations are shown in the diagram, figure 31. This diagram is an effort to depict the condition of the insect in orchards during the season as based on data obtained in the laboratory. Spring pupæ appeared shortly after

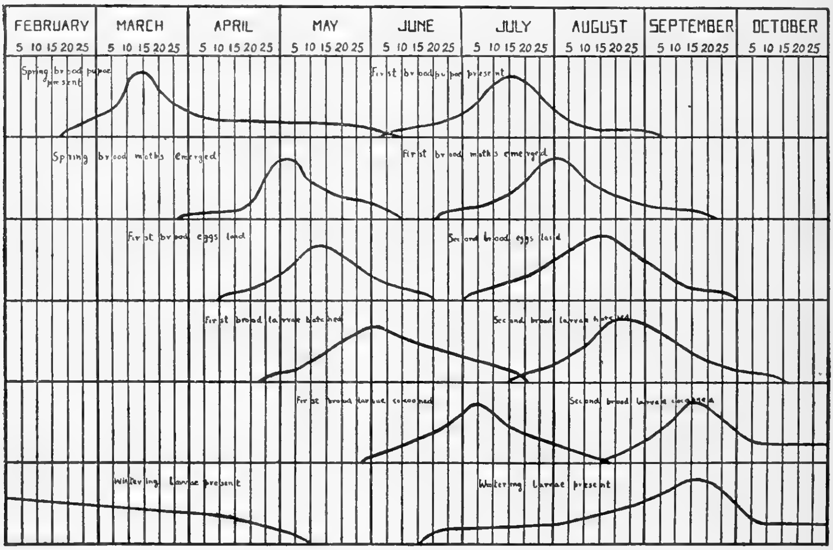

FIG. 31.—Diagram showing seasonal history of the codling moth during the season of 1910. (Original.)

the middle of February and continued to appear until June, reaching a maximum about April 4. Moths began to emerge March 28 and continued emerging until June 9, with an average maximum May 4. Oviposition of the first-brood eggs extended from April 10 to June 20 with a maximum about May 16, while the larvæ of the first brood began to hatch April 26 and continued hatching until July 22, reaching a maximum about May 29. The larvæ of the first brood cocooned from May 28 up to August 14 with a maximum about July 3. About June 4 the first-brood pupæ were present and continued until September 3, reaching a maximum about July 14. Emergence of the first-brood moths commenced June 22 and lasted three months or until September 22, with a maximum about August 4. Second-brood eggs were deposited from July 1 until September 28, reaching a

maximum about August 11, while the second-brood larvæ hatched from July 13 until October 12 with a maximum about August 20. The second-brood larvæ cocooned August 16 and on throughout the winter, with a maximum about September 16. The wintering larvæ of the first brood "to spin cocoons" began to do so about June 15, but by far the largest number of these came from the second or true overwintering brood. The life cycle of the codling moth from the first appearance of the spring pupæ until the last larva of the first brood cocooned occupied about six months. The second-brood life cycle from the first appearance of the first-brood pupæ up to the cocooning of the wintering larvæ in 1911 occupied a period of over eleven months.

SEASONAL-HISTORY STUDIES FOR 1911.

SPRING BROOD OF PUPÆ.

Time of pupation.—Records for the spring brood were kept in two series, one lot in small gelatin capsules, size No. 0, punctured with a pin, and the other in vials. Those in the capsules were taken from under bands in February and out of the larvæ thus secured only 41 per cent pupated. Of those that pupated 21.7 per cent died, the majority of these being early pupating individuals. The first larva pupated on March 2, the second March 14, and none after that until the last week of the month. Pupation continued until May 11, on which date the last larva became a pupa. The first adult appeared April 18 and the last June 8. Thus the actual period of time when pupæ were present extended from March 2 to June 8, or 98 days. In the field, however, adults were emerging from March 24 to June 20; thus pupæ were present from about February 12 until June 20, or 128 days. The longest pupal stage was 49 days, the shortest 30, and the average 41.9 days. Figure 32 shows the time of pupation for both capsule and vial material and also daily mean temperature. These data were compiled from records of 156 individuals.

Second series of larvæ.—Larvæ were taken from bands in the fall of 1910 and placed in vials, where they remained through the winter. Of these 25.2 per cent died before pupating and of the ones that developed into pupæ 23.2 per cent perished. The earliest pupa occurred March 16 and the latest May 11. The earliest adult issued April 26 and the latest June 11. Therefore the period when pupæ were present, March 16 to June 11, amounted to 87 days. The shortest pupal stage was 31 days, the longest 56, and the average 43.2 days. This exceeds the average for the capsule series by 1.3 days. There were 66 individuals in the vial series, of which 32 were males and one escaped before its sex could be determined. No attempt was made to credit any certain sex to the larvæ while in that stage as was done in 1910. The average male pupal stage was 41.8 days, while that

of the female was 44.3 days, or 2.5 days longer. In summarizing the two series we find that the earliest pupa occurred March 2, the latest pupa May 11, the earliest adult April 18, and the last adult June 11. The shortest pupal stage was 30 days, the longest 56, and the average

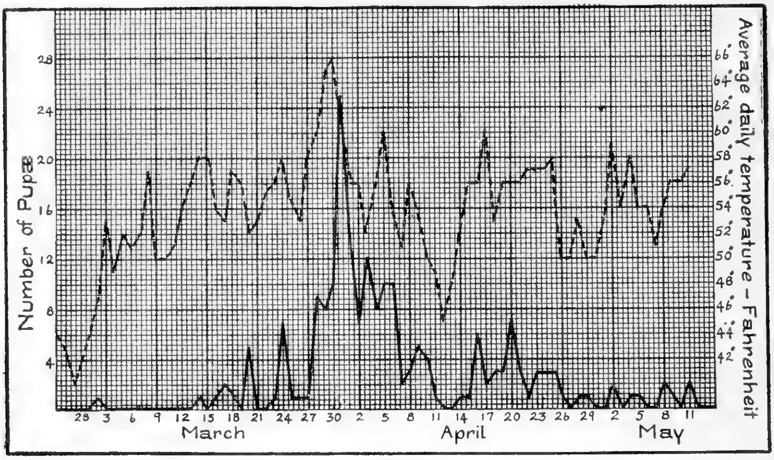

FIG. 32.—Diagram showing pupation of spring brood of larvæ, 1911. (Original.)

42.4 days. From the total adult emergence record (fig. 33) it will be seen that the earliest adult emerged on March 24 and the last on June 20, so that by using the average pupal period the earliest pos-

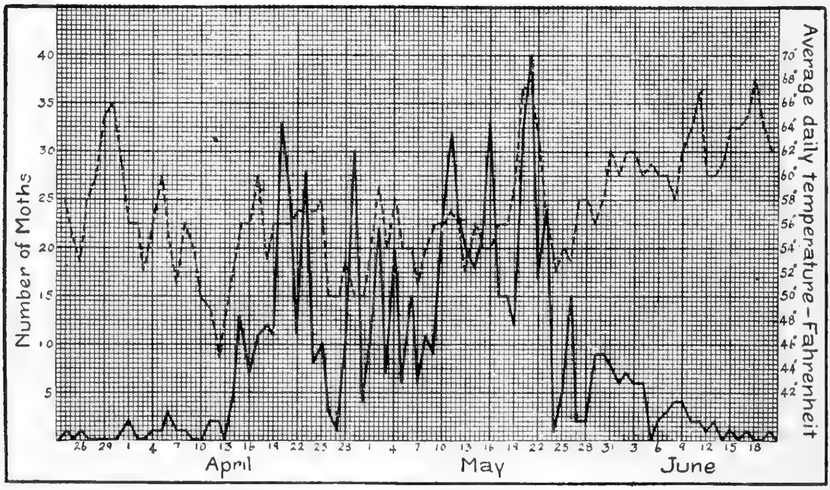

FIG. 33.—Diagram showing emergence of moths; overwintering brood of 1911. (Original.)

sible pupa must have occurred about February 9, and thus the theoretical span of the pupal period included the time between February 9 and June 20, or 131 days. Tables XXVIII and XXIX show, respectively, the pupal stages in the capsules and vials.

TABLE XXVIII.—*Spring brood of pupæ. Length of pupal stage of overwintering larvæ collected under bands in February, 1911, and reared in capsules.*

No. of individual.	Date of—		Length of pupal stage.	No. of individual.	Date of—		Length of pupal stage.
	Pupation.	Emergence.			Pupation.	Emergence.	
			Days.				*Days.*
1	Mar. 2	Apr. 20	49	46	Apr. 3	May 18	45
2	Mar. 14	Apr. 18	35	47	...do.....	May 19	46
3	Mar. 26	May 6	41	48	...do.....	May 16	43
4	Mar. 28	May 10	43	49	...do.....	...do.....	43
5	Mar. 29	May 6	38	50	...do.....	May 20	47
6	...do.....	May 9	41	51	Apr. 4	May 19	45
7	...do.....	May 10	42	52	...do.....	May 17	43
8	...do.....	...do.....	42	53	...do.....	May 18	44
9	Mar. 30	May 13	44	54	Apr. 5	May 15	40
10	...do.....	...do.....	44	55	...do.....	May 18	43
11	...do.....	May 10	41	56	...do.....	May 19	44
12	...do.....	May 12	43	57	...do.....	May 20	45
13	Mar. 13	...do.....	42	58	...do.....	...do.....	45
14	Mar. 31	May 13	43	59	...do.....	May 18	43
15	...do.....	...do.....	43	60	Apr. 6	May 20	44
16	...do.....	...do.....	43	61	...do.....	May 18	42
17	...do.....	May 15	45	62	...do.....	May 20	44
18	...do.....	May 12	42	63	...do.....	...do.....	44
19	...do.....	May 14	44	64	...do.....	May 19	43
20	...do.....	May 12	42	65	...do.....	May 20	44
21	...do.....	...do.....	42	66	...do.....	...do.....	44
22	...do.....	May 14	44	67	Apr. 9	May 21	42
23	...do.....	May 15	45	68	...do.....	...do.....	42
24	...do.....	May 14	44	69	Apr. 10	...do.....	41
25	Mar. 25	...do.....	44	70	...do.....	...do.....	41
26	Mar. 31	May 12	42	71	...do.....	...do.....	41
27	...do.....	May 14	44	72	Apr. 14	May 22	38
28	Apr. 1	May 11	40	73	Apr. 15	May 23	38
29	...do.....	May 16	45	74	Apr. 16	...do.....	37
30	...do.....	May 14	43	75	...do.....	May 22	36
31	...do.....	May 15	44	76	Apr. 17	May 24	37
32	...do.....	May 16	45	77	Apr. 19	May 27	38
33	...do.....	May 13	42	78	Apr. 20	May 26	36
34	...do.....	May 16	46	79	...do.....	...do.....	36
35	...do.....	May 13	42	80	...do.....	May 31	41
36	Apr. 2	May 14	42	81	Apr. 21	...do.....	40
37	...do.....	May 15	43	82	...do.....	...do.....	40
38	...do.....	...do.....	43	83	Apr. 24	June 1	38
39	...do.....	May 14	42	84	...do.....	...do.....	38
40	...do.....	...do.....	42	85	Apr. 25	May 31	36
41	...do.....	May 15	43	86	Apr. 26	June 4	39
42	Apr. 3	May 16	43	87	Apr. 28	June 3	36
43	...do.....	May 19	46	88	May 2	June 6	35
44	...do.....	May 16	43	89	...do.....	June 4	33
45	...do.....	May 18	45	90	May 9	June 8	30

TABLE XXIX.—*Spring brood of pupæ. Length of the pupal stage of overwintering larvæ collected from banded trees in 1910 and reared in vials.*

No. of individual.	Date of—		Sex.	Length of pupal stage.	No. of individual.	Date of—		Sex.	Length of pupal stage.
	Pupation.	Emergence.				Pupation.	Emergence.		
				Days.					*Days.*
1	Mar. 14	May 6	♂	43	34	Mar. 31	May 16	......	46
2	Mar. 16	Apr. 26	♂	41	35	...do.....	May 12	♂	42
3	Mar. 17	Apr. 29	♂	43	36	...do.....	May 16	♀	47
4	...do.....	Apr. 28	♂	42	37	...do.....	May 18	♂	48
5	Mar. 18	Apr. 30	♀	43	38	...do.....	May 16	♂	46
6	Mar. 20	May 1	♀	42	39	Apr. 1	...do.....	♀	45
7	...do.....	May 3	♂	44	40	...do.....	May 18	♂	47
8	...do.....	May 2	♂	43	41	...do.....	May 20	♀	49
9	...do.....	May 1	♂	43	42	...do.....	May 27	♀	56
10	...do.....	Apr. 30	♀	41	43	Apr. 3	May 19	♂	46
11	Mar. 23	May 4	♀	44	44	...do.....	May 20	♀	47
12	Mar. 24	May 5	♂	44	45	Apr. 5	May 21	♀	47
13	...do.....	May 8	♀	45	46	Apr. 4	...do.....	♀	47
14	...do.....	May 5	♂	42	47	Apr. 5	...do.....	♀	46
15	Mar. 25	...do.....	♀	41	48	...do.....	...do.....	♀	46
16	Mar. 26	May 8	♂	42	49	Apr. 8	May 22	♂	44
17	Mar. 28	...do.....	♂	41	50	...do.....	...do.....	♀	44
18	...do.....	May 9	♀	42	51	Apr. 9	May 21	♀	42
19	...do.....	May 10	♀	43	52	...do.....	May 22	♀	43
20	...do.....	May 6	♂	39	53	...do.....	May 18	♂	39
21	...do.....	May 11	♂	44	54	Apr. 10	May 22	♂	42
22	...do.....	May 10	♂	43	55	Apr. 11	...do.....	♂	41
23	Mar. 29	May 11	♀	43	56	Apr. 16	May 26	♂	40
24	...do.....	May 10	♀	42	57	...do.....	May 23	♂	37
25	...do.....	...do.....	♀	43	58	...do.....	May 30	♂	44
26	...do.....	May 12	♀	44	59	Apr. 18	May 26	♂	38
27	Mar. 30	May 13	♀	45	60	...do.....	May 28	♀	40
28	...do.....	May 15	♀	46	61	Apr. 20	May 29	♀	39
29	Mar. 31	May 13	♂	43	62	Apr. 21	...do.....	♀	38
30	...do.....	May 16	♀	46	63	Apr. 22	May 30	♂	38
31	...do.....	...do.....	♀	46	64	Apr. 23	June 1	♂	39
32	...do.....	...do.....	♀	46	65	...do.....	...do.....	♂	39
33	...do.....	...do.....	♀	46	66	May 11	June 11	♂	31

Table XXX shows the variations in the length of the pupal period for 156 individuals as recorded in Tables XXVIII and XXIX:

TABLE XXX.—*Spring brood of pupæ. Variation in the length of the pupal period as recorded in Tables XXVIII and XXIX.*

Pupæ.	Days.	Pupæ.	Days.	Pupæ.	Days.	Pupæ.	Days.
1	30	3	37	24	42	6	47
1	31	9	38	28	43	1	48
1	33	6	39	23	44	2	49
2	35	6	40	12	45	1	56
5	36	12	41	13	46		

Tables XXVIII and XXIX show that individuals which pupated early usually remained longer in the pupal state than those which later became pupæ.

Temperature conditions.—The temperature conditions influencing the pupal periods of the spring brood of pupæ are shown in the following table:

Table XXXI.—*Temperature conditions influencing the pupal period of the spring brood in degrees Fahrenheit.*

Month.	Maximum.	Minimum.	Mean.	Departure from normal.
	° F.	° F.	° F.	
March	63.3	46.0	54.6	+0.9
April	65.0	42.7	53.8	−2.5
May	69.2	43.8	56.5	−4.2
Average	65.8	44.2	55.0	

SPRING BROOD OF MOTHS.

Time of emergence of moths in the spring.—Figure 33 shows graphically the time of emergence and the relative abundance of moths of the spring brood with the corresponding daily mean temperature in degrees Fahrenheit. The records for these observations are given in Table XXXII.

Table XXXII.—*Emergence of spring moths, 1911, from wintering material collected on banded trees during 1910.*

Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.	Date.	Number of moths.
Mar. 24	1	Apr. 16	7	May 9	9	June 1	6
Mar. 25	0	Apr. 17	11	May 10	22	June 2	7
Mar. 26	1	Apr. 18	12	May 11	32	June 3	6
Mar. 27	0	Apr. 19	11	May 12	23	June 4	6
Mar. 28	0	Apr. 20	33	May 13	20	June 5	0
Mar. 29	0	Apr. 21	26	May 14	18	June 6	2
Mar. 30	0	Apr. 22	11	May 15	21	June 7	3
Mar. 31	0	Apr. 23	28	May 16	33	June 8	4
Apr. 1	2	Apr. 24	8	May 17	15	June 9	4
Apr. 2	0	Apr. 25	10	May 18	15	June 10	2
Apr. 3	0	Apr. 26	3	May 19	12	June 11	2
Apr. 4	1	Apr. 27	1	May 20	32	June 12	1
Apr. 5	1	Apr. 28	10	May 21	40	June 13	2
Apr. 6	3	Apr. 29	30	May 22	17	June 14	0
Apr. 7	1	Apr. 30	4	May 23	24	June 15	1
Apr. 8	1	May 1	10	May 24	1	June 16	0
Apr. 9	0	May 2	22	May 25	5	June 17	1
Apr. 10	0	May 3	7	May 26	15	June 18	0
Apr. 11	2	May 4	20	May 27	2	June 19	0
Apr. 12	2	May 5	6	May 28	2	June 20	1
Apr. 13	0	May 6	15	May 29	9		
Apr. 14	5	May 7	6	May 30	9		
Apr. 15	13	May 8	11	May 31	8		

The rise in temperature on March 27 seems to have started a few moths to emergence while the later rise on April 13 brought out a large number of adults, and it was at this time that the first absolute maximum occurred. From this time on to May 20 the temperature remained little changed, but on that date it rose and seemingly occasioned the second absolute maximum emergence, which occurred the next day. By May 28 emergence was on the wane and the temperature had little or nothing to do with emergence following. The majority of moths issued between April 20 and May 23, a maximum period of 33 days. The total period extended from March 24 to June 20, or 89 days.

Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the year before.—Larvæ were collected from beneath burlap bands weekly from June 6 to August 22, 1910, and each weekly lot was assigned to a separate jar. Records were then kept of the moths emerging from these jars for first-brood adults of 1910 and those which wintered over as larvæ for spring-brood moths in 1911. The material collected June 20 was, unfortunately, used for another purpose and so is excluded in these records. Table XXXIII indicates the daily emergence from each jar and the dates when collections were made. The percentages of adults issuing from each jar in 1910 and 1911 and the totals for both years are also given. It will be observed that the moths of the earlier collections mostly issued in 1910 as first-brood adults, while those of the later collections mostly wintered over to emerge as overwintering adults. Of all larvæ and pupæ collected only 53.7 per cent issued as adults. Of these the ratio of those emerging in 1910 to those emerging in 1911 was as 33 to 20, roughly speaking. Of the whole number of individuals collected 33.4 per cent issued as adults in 1910 and 20.3 per cent in 1911. The time of collection of larvæ in the summer had no influence on the time of emergence of adults the following spring.

TABLE XXXIII.—*Adult emergence of the first and second broods from band material collected in 1909.*

Jar No.	Date of collection.	Number collected—		Total.	Emergence—					
		Larvæ.	Pupæ.		1910		1911		1910+1911	
	1910				*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
C- 1	June 6	22	6	28	8	28	0	0	8	28
C- 2	June 13	22	1	77	32	41.5	0	0	32	41.5
C- 4	June 27	173	0	173	68	39.3	33	19.1	101	58.4
C- 5	July 4	114	3	117	45	38.5	34	29	79	67.5
C- 6	July 11	326	28	354	123	34.7	78	22	201	56.7
C- 7	July 18	203	13	216	80	37	32	14.8	112	51.8
C- 8	July 25	102	9	111	23	20.7	22	19.8	45	40.5
C- 9	Aug. 1	41	5	46	12	26.1	16	34.7	28	60.8
C-10	Aug. 8	18	1	19	0	0	7	36.8	7	36.8
C-11	Aug. 15	13	5	18	2	11.1	7	38.9	9	50
C-12	Aug. 27	20	0	20	1	5	10	50	11	55
	Total.	1,108	71	1,179	394	33.4	239	20.3	633	53.7

Time during the day when moths emerged.—Observations on 100 moths were taken to determine what time of the day emergence was most common. Jars in which pupæ for emergence were kept were examined four times a day for 14 days. The times of examination were 9 a. m., 11 a. m., 1 p. m., and 4 p. m. Out of the 100 moths only 9 issued between 4 p. m. and 9 a. m., 44 emerged between 9 a. m. and 11 a. m., 42 between 11 a. m. and 1 p. m., and the remaining 5 between 1 p. m. and 4 p. m. Thus it seems that from 9 a. m. until 1 p. m. is the customary time of emergence. (See Table XXXIV.)

TABLE XXXIV.—*Spring brood of moths. Time during the day when moths emerged.*

Date.	Number emerging before—				Total emergence.
	9 a. m.	11 a. m.	1 p. m.	4 p. m.	
Apr. 26...	2	0	0	0	2
Apr. 28...	0	1	3	3	7
Apr. 29...	1	11	12	0	24
May 1....	2	3	0	0	5
May 2....	0	12	5	1	18
May 3....	1	4	1	0	6
May 4....	0	6	4	0	10
May 6....	0	0	6	0	6
May 8....	1	0	2	0	3
May 9....	1	1	2	0	4
May 10...	1	3	2	0	6
May 11...	0	3	3	0	6
May 12...	0	0	1	1	1
May 15...	0	0	1	0	1
Total..	9	44	42	5	100

Period of oviposition.—Although moths were placed in an oviposition cage with apples as soon as they emerged, no eggs were observed until June 1. After that time there was no difficulty in obtaining eggs. In the field eggs occurred early in April. No eggs could be obtained from single pairs of spring-brood moths, and thus no data were obtained as to the number of eggs a single female could deposit. In April and May, 1911, the mean temperature was considerably below normal and possibly this fact may account for the moths refusing to oviposit on the apples. From June 2 to 9 maximum oviposition took place.

Longevity of spring brood of moths.—Records were kept relative to the length of life of 40 moths which were placed in two jars and which were fed on grape juice and brown sugar. The results of these observations are given in Table XXXV and the summary of the results in Table XXXVI.

TABLE XXXV.—*Spring brood of moths, 1911. Length of life of the moths.*

Cage A.				Cage B.			
Number of moths.	Date of—		Days.	Number of moths.	Date of—		Days.
	Emergence.	Death.			Emergence.	Death.	
2	Apr. 29....	May 1.....	2	1	May 3.....	May 4.....	1
1	.....do.....	May 2.....	3	2	.....do.....	May 5.....	2
3	.....do.....	May 3.....	4	1	.....do.....	May 7.....	4
1	.....do.....	May 4.....	5	3	.....do.....	May 10....	7
1	.....do.....	May 5.....	6	4	.....do.....	May 12....	9
1	.....do.....	May 7.....	8	5	.....do.....	May 13....	10
1	.....do.....	May 8.....	9	1	.....do.....	May 14....	11
1	.....do.....	May 9.....	10				
4	.....do.....	May 12....	13	17			44
1	.....do.....	May 13....	14				
2	.....do.....	May 14....	15				
2	.....do.....	May 16....	17				
3	.....do.....	May 17....	18				
23			124				

The average length of life of the moths in cage A was 10.5 days, while that of those in cage B was 7.41 days. The combined average was thus 9.19 days.

TABLE XXXVI.—*Longevity of moths of spring brood. Summary of Table XXXV.*

Observations.	Days.
Average	9.19
Maximum	18
Minimum	1

FIRST GENERATION.

FIRST BROOD OF EGGS.

Incubation period.—In the preceding pages the length of the period of egg deposition was considered under the habits of the moth.

A record of the length of the egg stage for 34 eggs is shown in Table XXXVII. As mentioned before, the earliest emerging moths would not oviposit in the cages, and it is probable that all eggs deposited previous to June 1 required from 15 to 18 days for the egg stage.

TABLE XXXVII.—*First-brood eggs. Incubation period of eggs laid in the rearing cages.*

No. of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date.	Number of eggs.	
									Days.
1	1	June 1	June 7	1	June 14	1	June 16	1	15
2	3	June 2	June 5	3	June 15	3	June 17	3	15
3	4	...do...	June 6	4	...do...	4	...do...	4	15
4	3	...do...	...do... June 8	2 1	...do... June 16	2 1	...do	3	15
5	5	June 4	June 7	5	June 15 June 16	4 1	June 18	5	14
6	4	June 5	June 8	4	June 17	4	...do...	4	13
7	2	...do...	...do... June 9	1 1	June 18	2	June 19	2	14
8	2	June 8	June 10 June 11	1 1	...do...	2	...do...	2	11
9	4	...do...	...do...	4	...do...	4	...do...	4	11
10	2	...do...	June 12	2	...do...	2	...do...	2	11
11	3	June 9	June 11 June 12	1 2	...do...	3	...do...	3	10
12	1	June 10	...do...	1	June 19	1	June 20	1	10
13	1	June 11	June 13	1	June 20	1	June 23	1	12
14	1	June 12	...do...	1	...do...	1	...do...	1	11
15	8	June 16	June 18	8	June 26	8	June 28	8	12

Table XXXVIII shows a summary of Table XXXVII.

TABLE XXXVIII.—*Incubation period of first-brood eggs. Summary of Table XXXVII.*

Observations.	Days of incubation.
Average	12.77
Maximum	15
Minimum	10

From Table XXXVIII it is seen that the maximum egg stage was 15 days, the minimum 10, and the average 12.77 days. The average time before appearance of the red ring was 3 days, and the time before appearance of the black spot 11 days.

FIRST BROOD OF LARVÆ.

Time of hatching.—The first larva to appear from eggs laid by captive moths hatched June 16. In the field at this time some full-sized larvæ were noticed, which were in all probability just-hatched larvæ about May 1, but, as has been stated before, the captive moths refused to deposit eggs before June 1. From eggs laid after this date 16 larvæ hatched and were placed on apples to get data on the feeding period and post-larval stage. Only six of these transformed into the pupæ and Table XXXIX records their larval history.

TABLE XXXIX.—*First-brood larvæ: Feeding period and length of the post-larval stage.*

No. of larva.	Sex.	Date when— Larva hatched.	Larva entered apple.	Larva left apple.	Larva pupated.	Length of larval stage.
						Days.
1	♂	June 17	June 17	July 12	July 13	26
2	♀	June 19	June 19	July 17	July 26	37
3	♂	...do....	...do....	July —[a]	July 23	34
4	♀	...do....	...do....	July 13	July 31	42
5	♂	June 20	June 20	July 17	July 27	37
6	?	June 28	June 28	July 23	July 30	32

[a] Larva spun cocoon in apple.

The average length of the total larval stage was 34.67 days, including the time taken by the larva to spin its cocoon after leaving the apple, which is the post-larval stage. As this period varies considerably, in the above six instances from 1 to 18 days, the true larval stage or feeding period is found by simply taking the time of larval existence until the worm leaves the apple. In the instance of larva No. 3 the cocoon was spun inside the apple, so the time spent in feeding could not be determined. The average time taken by the other five to attain full growth was 25.8 days, with a maximum of 28 and a minimum of 24 days.

Number of larvæ developing in each apple.—Several larvæ entered the same apple in numerous instances, but never more than two developed. In the orchard usually but one larva is found in each apple, although the entrance holes of several often can be observed. An apple from which a larva of the first generation has issued may later contain a larva of the succeeding generation.

FIRST BROOD OF PUPÆ.

Time of pupation and length of pupal stage.—The larvæ for this record were collected from banded trees and placed in gelatin capsules and vials to obtain pupation records. Practically no difference in length of pupal period was found in those kept in capsules and in those in vials. Of the 123 larvæ placed for pupation 52 died, and of the 71 remaining 12 elected to pass the winter as larvæ. The pupation record in Table XL is therefore recorded from only 59 individuals. The earliest pupa occurred July 8, the latest August 16; the earliest adult issued July 27, the latest September 13. Consequently the pupal period ranged from July 8 to September 13, a

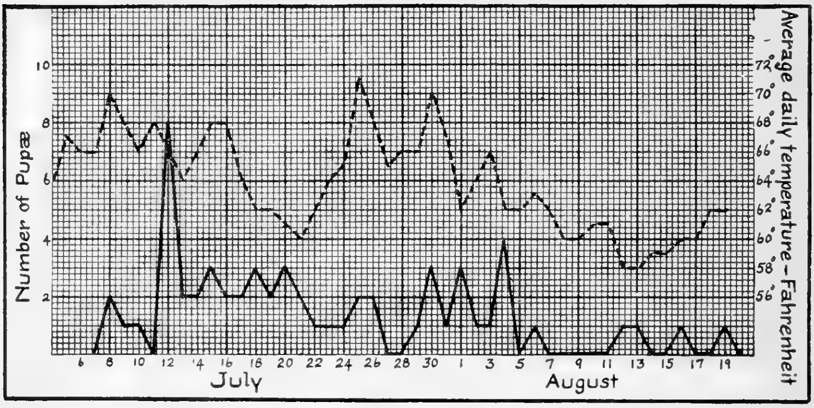

FIG. 34.—Diagram showing first-brood pupæ, 1911. (Original.)

period of 68 days. The shortest pupal stage was 18 days, the longest 37, and the average 23.12 days. Using this average we find that probably the earliest pupa occurred July 4, and as the latest adult (see adult emergence record, Table XLIII) issued September 29 we have a theoretical range for the pupal period of 87 days.

Of the larvæ under observation there were 21 males and 33 females, the average pupal stage of the former being 22.95 days and that of the latter 23.45 (see Table XLI), the females thus requiring half a day longer to develop into adults. Five individuals escaped before their sex could be determined.

Figure 34 shows graphically the time of pupation of the first brood.

TABLE XL.—*First-brood pupæ: Length of the pupal period from material collected in 1911 on banded trees.*

No. of individual.	Date of— Pupation.	Date of— Emergence.	Sex of moth.	Length of pupal period.	No. of individual.	Date of— Pupation.	Date of— Emergence.	Sex of moth.	Length of pupal period.
				Days.					*Days.*
1	July 8	July 27	♀	19	31	July 20	Aug. 13	......	24
2	...do....	...do....	♀	19	32	July 21	Aug. 11	♀	21
3	July 9	...do....	♀	18	33	...do....	Aug. 12	♀	22
4	July 10	July 31	♀	21	34	July 22	Aug. 17	♂	26
5	July 12	...do....	♀	19	35	July 24	Aug. 14	......	21
6	...do....	Aug. 1	♂	20	36	July 25	Aug. 17	♂	23
7	...do....	...do....	♂	20	37	...do....	...do....	♀	23
8	...do....	...do....	♀	20	38	July 26	Aug. 19	♀	24
9	...do....	...do....	♀	20	39	...do....	Aug. 20	♀	25
10	...do....	Aug. 2	......	21	40	July 29	Aug. 21	♀	23
11	...do....	Aug. 3	♀	22	41	July 30	Aug. 23	♀	24
12	...do....	Aug. 6	♀	25	42	...do....	...do....	♂	24
13	July 13	Aug. 1	♂	19	43	...do....	Aug. 28	♂	29
14	...do....	Aug. 3	♂	21	44	July 31	Aug. 24	♀	24
15	July 14	...do....	♂	20	45	Aug. 1	Aug. 26	♀	25
16	...do....	...do....	♂	20	46	...do....	Aug. 27	♀	26
17	July 15	...do....	......	19	47	...do....	...do....	♀	26
18	...do....	Aug. 5	♂	21	48	Aug. 2	Aug 26	♀	24
19	...do....	Aug. 7	......	23	49	Aug. 3	Aug. 30	♀	27
20	July 16	Aug. 6	♂	21	50	...do....	Sept. 9	♀	37
21	...do....	Aug. 19	♂	34	51	Aug. 4	Aug. 28	♀	24
22	July 17	Aug. 5	♀	19	52	...do....	Aug. 29	♂	25
23	...do....	Aug. 7	♀	21	53	...do....	...do....	♀	25
24	July 18	Aug. 8	♂	21	54	...do....	Aug. 31	♀	27
25	...do....	Aug. 9	♂	22	55	Aug. 6	Sept. 2	♀	27
26	...do....	Aug. 8	♀	22	56	Aug. 12	Sept. 7	♂	26
27	July 19	Aug. 9	♀	21	57	Aug. 13	Sept. 2	♂	20
28	...do....	Aug. 14	♀	26	58	Aug. 16	Sept. 13	♀	28
29	July 20	Aug. 11	♂	22	59	Aug. 19	...do....	♂	25
30	...do....	Aug. 12	♂	23					

The variations in the length of the pupal stage are shown in Table XLI and a summary of Table XL in Table XLII.

TABLE XLI.—*First-brood pupæ: Variations in the length of the pupal period for 59 individuals.*

Pupæ.	Days.	Pupæ.	Days.
1	18	6	25
6	19	5	26
7	20	3	27
10	21	1	28
5	22	1	29
5	23	1	34
7	24	1	37

TABLE XLII.—*First-brood pupæ: Summary of Table XL.*

Observations.	Days in the pupal stage.
Average..........	23.12
Maximum.......	37
Minimum........	18

FIRST BROOD OF MOTHS.

Time of emergence.—On July 22 the first moths emerged from band material collected July 6. The emergence reached its maximum August 19 and continued on until September 29. Most of the moths,

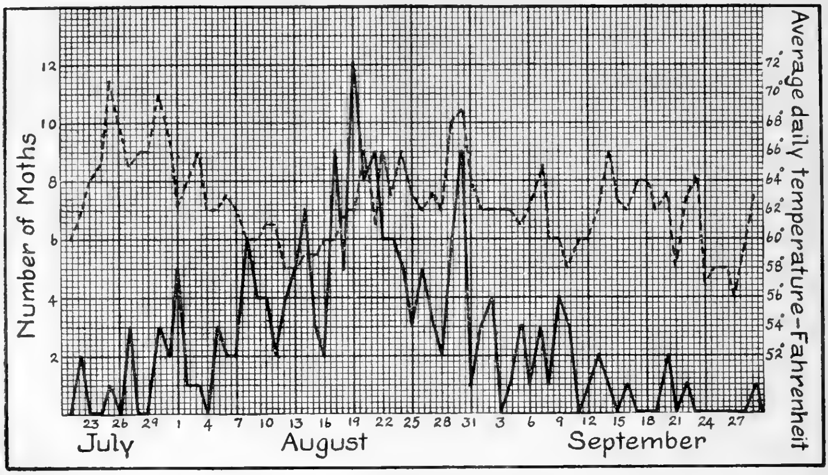

FIG. 35.—Diagram showing emergence of first-brood moths, 1911. (Original.)

however, emerged in August and the first few days in September. As can be seen from figure 35 and Table XLIII the emergence is drawn out so that it covers a period of 70 days:

TABLE XLIII.—*Emergence of moths of the first brood: Material from banded trees.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 22	2	Aug. 11	2	Aug. 25	3	Sept 9	4
July 25	1	Aug. 12	4	Aug. 26	5	Sept. 10	3
July 27	3	Aug. 13	5	Aug. 27	3	Sept. 12	1
July 30	3	Aug. 14	7	Aug. 28	2	Sept. 13	2
July 31	2	Aug. 15	3	Aug. 29	6	Sept. 14	1
Aug. 1	5	Aug. 16	2	Aug. 30	9	Sept. 16	1
Aug. 2	1	Aug. 17	9	Aug. 31	1	Sept. 20	2
Aug. 3	1	Aug. 18	5	Sept. 1	3	Sept. 22	1
Aug. 5	3	Aug. 19	12	Sept. 2	4	Sept. 29	1
Aug. 6	2	Aug. 20	8	Sept. 4	1		
Aug. 7	2	Aug. 21	9	Sept. 5	3		157
Aug. 8	6	Aug. 22	6	Sept. 6	1		
Aug. 9	4	Aug. 23	6	Sept. 7	3		
Aug. 10	4	Aug. 24	5	Sept. 8	1		

Oviposition period.—Nearly all of the moths which emerged were utilized for securing eggs by confining them in Riley cages in which apples had been suspended on strings. The moths oviposited readily and a large number of eggs were secured. The first eggs were obtained on August 10, or 19 days after the first moths emerged, which was on July 22. The earliest moths did not oviposit in the cages but it is probable eggs were present in the field about the middle of July. The oviposition period continued throughout August and September.

LIFE CYCLE OF FIRST GENERATION.

Along with other rearing experiments to obtain the length of the egg stage and the feeding periods of the larvæ a number of adults were reared from the egg to ascertain the complete life cycle. In this experiment only six individuals were carried through the entire period and the details of the work are shown in Table XLIV.

Table XLV is a summary of Table XLIV and shows that the average life cycle from egg to egg (allowing 3 days after the moths emerge before eggs are laid) was 71.3 days, the maximum 77 days and the minimum 67 days. Adding the average egg stage, or 12.77 days, the average feeding period, or 25.08 days, the average post-larval stage, or 9 days, the average pupal stage, or 23.12 days, and allowing 3 days for eggs to be deposited after the moths emerge, a total of 72.95 days is obtained, or very close to the average life cycle, from actual rearing experiments.

Table XLIV.—*Life cycle of the first generation.*

No. of individual.	Sex.	Date of—				Length of egg stage.
		Deposition.	Red ring.	Black spot.	Larva hatching.	*Days.*
1	♂	June 2	June 5	June 15	June 17	15
2	♀	June 8	June 10	June 18	June 19	11
3	♂	...do....	June 11	...do....	...do....	11
4	♀	...do....	...do....	...do....	...do....	11
5	♂	June 10	June 12	June 19	June 20	10
6	?	...do....	June 18	June 26	June 28	12

No. of individual.	Date of—			Length of larval stage.	Emergence of adult.	Length of pupal stage.	Length of life cycle. Eggs to adult.	Total length of life cycle. Egg to egg.
	Larva entering apple.	Larva leaving apple.	Pupation.	*Days.*		*Days.*	*Days.*	*Days.*
1	June 17	July 12	July 13	26	Aug. 5	23	64	67
2	June 19	July 17	July 26	37	Aug. 17	22	70	73
3	...do....	....	July 23	34	Aug. 13	21	66	69
4	...do....	July 13	July 31	42	Aug. 21	21	74	77
5	June 20	July 17	July 27	37	Aug. 18	22	69	72
6	June 28	July 23	July 30	32	Aug. 22	23	67	70

Table XLV.—*Summary of Table XLIV.*

Observation.	Total life cycle. Egg to adult.	Total life cycle. Egg to egg.
	Days.	*Days.*
Average	68.3	71.3
Maximum	74	77
Minimum	64	67

SECOND GENERATION.

SECOND BROOD OF EGGS.

Incubation period.—In all, 845 eggs were deposited during the 33 days on apples in the cages used for this purpose. No record was kept as to how many eggs a single female deposited, but, judging from the number of female moths confined and the eggs deposited by them, the average for each female must have been about 40. No record was kept as to the time of day the females selected for oviposition, but observation throughout the day showed moths ovipositing from early in the morning until evening. Table XLVI shows the length of the egg stage for 760 individuals.

TABLE XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages.*

No. of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	
									Days.
1	3	Aug. 10	....	....	Aug. 21	3	Aug. 23	3	13
2	9	Aug. 16	Aug. 19	9	Aug. 25 Aug. 26	8 1	Aug. 27 Aug. 28 Aug. 29	1 6 1	11 12 13
4	46	Aug. 17	Aug. 20 Aug. 21	30 4	..do..... Aug. 27 Aug. 28	39 3 3	Aug. 28 Aug. 29 Aug. 30 Aug. 31 Sept. 1	6 23 9 2 1	11 12 13 14 15
5	8	...do.....	Aug. 20 Aug. 21	6 1	Aug. 26 Aug. 27	6 1	Aug. 29	6	12
6	4	...do.....	Aug. 20	2	Aug. 26 Aug. 27	3 1	..do.....	3	12
8	14	Aug. 18	..do..... Aug. 21 Aug. 22	4 5 1	Aug. 28	10	Aug. 30 Aug. 31	3 4	12 13
9	2	...do.....	Aug. 21	1	Aug. 27	1	Aug. 29	1	11
10	1	...do.....	...do.....	1	Aug. 28	1	Aug. 30	1	12
11	25	Aug. 28	Aug. 20 Aug. 21	5 16	Aug. 27 Aug. 28	6 19	Aug. 29 Aug. 30 Aug. 31 Sept. 1	5 15 2 1	11 12 13 14
12	2	Aug. 18	...do.....	2	...do.....	2	Aug. 30	2	12
13	4	Aug. 19	Aug. 22	2	Aug. 29 Aug. 30	1 2	Aug. 31 Sept. 1 Sept. 2	1 1 1	12 13 14
14	9	...do.....	Aug. 21	6	Aug. 28	9	Aug. 30 Aug. 31	3 6	11 12
15	3	...do.....	..do..... Aug. 22	1 1	...do..... Aug. 29	2 1	Aug. 30 Aug. 31	1 2	11 12
16	6	...do.....	Aug. 21 Aug. 22	1 3	Aug. 28	5	Aug. 30 Aug. 31 Sept. 1 Sept. 2	1 2 1 1	11 12 13 14
17	4	...do.....	....	....	Aug. 29 Aug. 30	2 1	Sept. 1 Sept. 2	1 1	13 14
18	4	Aug. 20	Aug. 22 Aug. 23	3 1	..do.....	4	Sept. 1	4	12
19	11	...do.....	Aug. 22 Aug. 23	6 2	Aug. 29 Aug. 30	5 5	Aug. 31 Sept. 1 Sept. 2	1 8 1	11 12 13
20	11	...do.....	Aug. 22	9	Aug. 29 Aug. 30	3 4	Aug. 31 Sept. 1	1 8	11 12
21	15	...do.....	..do..... Aug. 23	14 1	Aug. 29 Aug. 30	11 4	Aug. 31 Sept. 1	2 12	11 12
22	2	...do.....	...do.....	2	Aug. 29	2	..do..... Sept. 2	1 1	12 13
23	3	Aug. 21	Aug. 24	2	Aug. 31	3	Sept. 1 Sept. 2	1 1	11 12
24	20	...do.....	Aug. 23 Aug. 24	2 14	..do.....	18	Sept. 1 Sept. 2	6 9	11 12
25	16	...do.....	Aug. 23 Aug. 24	1 11	..do.....	16	Sept. 1 Sept. 2	5 6	11 12

TABLE XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages*—Continued.

No. of apple.	Number of eggs.	Date of deposition.	Red ring. Date of appearance.	Red ring. Number of eggs.	Black spot. Date of appearance.	Black spot. Number of eggs.	Hatched. Date of appearance.	Hatched. Number of eggs.	Length of egg stage.
									Days.
26	7	Aug. 21	Aug. 24	4	Aug. 31	6	Sept. 1 Sept. 2 Sept. 4	1 3 1	11 12 14
28	12	...do.....	..do..... Aug. 25	9 3	..do.....	12	Sept. 1 Sept. 2 Sept. 3	4 7 1	11 12 13
29	20	...do.....	Aug. 24 Aug. 25	8 7	..do.....	18	Sept. 1 Sept. 2	3 15	11 12
30	25	Aug. 22	...do.....	15	..do..... Sept. 1	4 20	..do..... Sept. 3 Sept. 4	1 22 1	11 12 13
31	6	...do.....	...do.....	6	Aug. 31 Sept. 1	1 5	Sept. 3	6	12
32	3	...do.....	...do.....	3	Aug. 31 Sept. 1	1 2	Sept. 2 Sept. 3	1 2	11 12
33	13	...do.....	..do..... Aug. 26	5 2	Aug. 31 Sept. 1	7 5	Sept. 2 Sept. 3 Sept. 5	5 6 1	11 12 14
34	8	...do.....	Aug. 25	7	Aug. 31 Sept. 1	1 7	Sept. 2 Sept. 3	1 7	11 12
35	24	...do.....	..do..... Aug. 26	3 3	Aug. 31 Sept. 1	20 4	Sept. 2 Sept. 3	11 13	11 12
36	5	Aug. 23	...do.....	3	Sept. 1 Sept. 2	1 4	..do.....	5	11
37	4	...do.....	...do.....	2	...do.....	4	Sept. 4	4	12
38	7	...do.....	..do..... Aug. 28	1 1	..do.....	7	..do..... Sept. 5 Sept. 6	2 4 1	12 13 14
39	11	...do.....	Aug. 26 Aug. 28	4 1	...do..... Sept. 3	5 1	Sept. 4 Sept. 5	3 3	12 13
40	14	...do.....	Aug. 26	9	Sept. 2	14	Sept. 4	14	12
41	6	...do.....	..do..... Aug. 28	4 2	..do..... Sept. 3 Sept. 4	4 1 1	...do..... Sept. 5 Sept. 6	3 2 1	12 13 14
42	27	...do.....	Aug. 26 Aug. 28	16 4	Sept. 2 Sept. 3	25 2	Sept. 4 Sept. 5	18 7	12 13
43	29	Aug. 24	Aug. 27 Aug. 28	16 7	...do..... Sept. 5	26 3	..do..... Sept. 6 Sept. 8	7 21 1	12 13 15
44	19	...do.....	Aug. 27	18	Sept. 3 Sept. 4 Sept. 5	17 1 1	Sept. 5 Sept. 6 Sept. 7	9 8 2	12 13 14
45	25	...do.....	...do.....	19	Sept. 3 Sept. 4	23 2	Sept. 5 Sept. 6 Sept. 7	14 8 2	12 13 14
46	10	...do.....	...do.....	6	Sept. 3	10	Sept. 5 Sept. 6	7 3	12 13
47	20	...do.....	...do.....	17	...do.....	20	Sept. 5 Sept. 6	8 12	12 13
48	40	Aug. 25	Aug. 28	27	Sept. 4 Sept. 5	33 4	Sept. 7 Sept. 8	34 2	13 14
49	36	...do.....	...do.....	29	Sept. 4 Sept. 5	33 3	Sept. 7 Sept. 8	33 2	13 14
50	21	...do.....	...do.....	18	Sept. 4	21	Sept. 7 Sept. 8	20 1	13 14
51	4	...do.....	...do.....	3	...do.....	3	Sept. 7	3	13
52	3	...do.....	...do.....	1	Sept. 4 Sept. 7	2 1	Sept. 5 Sept. 7	1 1	11 13
53	15	Aug. 26	Aug. 30	9	Sept. 5 Sept. 6	3 12	Sept. 8 Sept. 9	13 2	13 14
54	4	...do.....	...do.....	3	Sept. 7	3	Sept. 8	3	13
55	23	...do.....	...do.....	20	Sept. 5 Sept. 6	9 14	..do.....	22	13
56	17	...do.....	...do.....	11	Sept. 5 Sept. 6 Sept. 7	9 7 1	..do.....	16	13
57	9	...do.....	...do.....	7	Sept. 5 Sept. 6 Sept. 7	3 5 1	..do..... Sept. 9	8 1	13 14
58	20	...do.....	...do.....	16	Sept. 5 Sept. 6	4 15	Sept. 8	19	13
59	17	Aug. 27	Aug. 31	11	..do..... Sept. 7	7 8	Sept. 7 Sept. 8 Sept. 9 Sept. 10	1 6 8 2	11 12 13 14

TABLE XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages*—Continued.

No. of apple.	Number of eggs.	Date of deposition.	Red ring.		Black spot.		Hatched.		Length of egg stage.
			Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	Date of appearance.	Number of eggs.	
									Days.
60	9	Aug. 27	Aug. 31	8	Sept. 6 Sept. 7 Sept. 8	2 6 1	Sept. 8 Sept. 9 Sept. 10	3 5 1	12 13 14
61	2	...do.....	...do.....	1	Sept. 7	1	Sept. 9	1	13
62	2	...do.....	...do.....	2	Sept. 6	2	Sept. 8	2	12
63	7	Aug. 28	Sept. 1	5	Sept. 8 Sept. 9 Sept. 11	4 2 1	Sept. 11 Sept. 12	6 1	14 15
64	7	...do.....	...do.....	6	Sept. 8 Sept. 9	5 2	Sept. 10 Sept. 11 Sept. 12	1 4 2	13 14 15
65	5	...do.....	...do.....	5	Sept. 7 Sept. 8 Sept. 9	1 3 1	Sept. 9 Sept. 10	1 4	12 13
66	8	...do.....	...do.....	8	Sept. 7 Sept. 8	5 3	..do.....	8	13
67	2	Aug. 29	...do.....	2	...do.....	2	Sept. 11	2	13
68	5	...do.....	...do.....	5	..do..... Sept. 9	3 2	...do..... Sept. 12	4 1	13 14
69	3	...do.....	...do.....	3	Sept. 8	3	Sept. 11	3	13
70	5	Aug. 30	..do..... Sept. 2	1 3	Sept. 10 Sept. 11 Sept. 12	2 2 1	Sept. 13 Sept. 14	3 2	14 15
71	3	Aug. 31	..do..... Sept. 7	1 1	Sept. 10 Sept. 12	1 1	Sept. 13 Sept. 14	1 1	13 14
72	7	...do.....	Sept. 4	1	...do.....	6	...do.....	4	14
73	2	...do.....	....	....	...do.....	2	...do.....	2	14
74	7	Sept. 1	Sept. 4 Sept. 7	3 3	Sept. 13	7	Sept. 15	7	14
75	22	...do.....	Sept. 4 Sept. 7	5 10	..do.....	21	..do..... Sept. 16	15 1	14 15
76	4	Sept. 3	...do.....	4	Sept. 15	4	Sept. 17	4	14
77	16	Sept. 4	...do.....	4	....	....	Sept. 18	4	14
78	4	Sept. 12	....	....	Sept. 22	4	Sept. 25	4	13

From Table XLVI it will be seen that the average egg stage was 12.5 days, the later individuals remaining in the egg slightly longer than the earlier, a phenomenon probably due to the gradual lowering of the temperature. Out of 845 eggs deposited, 760, or a fraction under 90 per cent, hatched. As can be seen from a study of Table XLVI the red ring is not a constant factor in the egg development, since it could be discovered in only 610 individuals. Mortality is about equally great before and after the appearance of the black spot. Table XLVII shows the variations in the length of the egg stage as recorded in Table XLVI.

TABLE XLVII.—*Second-brood eggs: Variations in the length of the egg stage as recorded in Table XLVI.*

Number of eggs.	Days.	Number of eggs.	Days.
68	11	8	15
301	12		
307	13	760	
76	14		

Table XLVIII is a summary of Table XLVI and shows the average, maximum, and minimum length of the egg stage.

TABLE XLVIII.—*Second-brood eggs: Summary of Table XLVI.*

Observations.	Length of the egg stage.
	Days.
Average........	12.5
Maximum........	15
Minimum........	11

SECOND BROOD OF LARVÆ.

Time of hatching.—Eggs obtained in the cages hatched from early August until September 25, but as the first moths did not oviposit in confinement just-hatched larvæ in numbers were probably in evidence in the field from the latter part of July until the middle of October, when most varieties of apples were picked.

Feeding period.—Apples on which eggs had been laid were placed in jelly glasses to obtain a record of the time taken by the larval development in the fruit. Although in most cases several larvæ entered the same fruit more than two full-grown larvæ never issued from the same fruit. The apples used were yellow Newtown Pippins and were large enough to provide food for several worms. The larvæ have a habit of coming out of the apple, wandering around the glass for a few days, and then entering the fruit again, thus extending the period of their growth. This habit may account in part for the large variation in the length of the period between hatching and the final emergence from the fruit for the purpose of spinning the wintering cocoon. The maximum time spent in the fruit was 79 days and the minimum 43, with an average of 58.15 days.

Table XLIX gives the record of the time spent in the fruit of 39 individuals.

TABLE XLIX.—*Second-brood larvæ: Time spent in the fruit.*

No. of apple.	Larva hatched.	Larva emerged from fruit.	Days in fruit.	No. of apple.	Larva hatched.	Larva emerged from fruit.	Days in fruit.
13	Sept. 1	Oct. 21	50	53	Sept. 7	Nov. 22	76
28	Sept. 2	Nov. 7	66	54	Sept. 8	Nov. 2	55
29	...do.....	Nov. 2	61	55	...do.....	Nov. 21	74
33	Sept. 3	Oct. 27	54	56	...do.....	Nov. 5	58
34	...do.....	Nov. 1	59	57	...do.....	Nov. 26	79
35	Sept. 2	Oct. 22	50	59	Sept. 9	Nov. 13	65
36	Sept. 3	Nov. 12	70	60	Sept. 8	Oct. 23	45
36	Sept. 4	Oct. 20	46	60	Sept. 10	Nov. 24	75
37	Sept. 3	Oct. 22	49	61	Sept. 9	Oct. 27	48
40	Sept. 5	Oct. 20	45	61	...do.....	Oct. 31	52
41	Sept. 4	Nov. 4	61	62	Sept. 8	Nov. 15	68
42	Sept. 5	...do.....	60	63	Sept. 11	Oct. 30	49
43	Sept. 4	Nov. 3	60	64	...do.....	Nov. 11	61
45	Sept. 6	Oct. 14	43	65	Sept. 10	Nov. 1	52
46	...do.....	Nov. 5	60	69	Sept. 11	Nov. 5	55
47	Sept. 5	Nov. 14	70	75	Sept. 15	Nov. 2	48
49	Sept. 6	Oct. 19	43	75	...do.....	Nov. 20	66
50	Sept. 7	Nov. 8	62	78	...do.....	Nov. 12	58
51	...do.....	Oct. 31	54	79	...do.....	Nov. 9	55
52	...do.....	Nov. 12	66				

Table L, a summary of Table XLIX, shows the average maximum and minimum time spent by the second-brood larvæ in feeding.

TABLE L.—*Feeding period of second-brood larvæ: Summary of Table XLIX.*

Observations.	Days in the fruit.
Average	58.15
Maximum	79
Minimum	43

Time of leaving the fruit for wintering.—Table XLIX shows that the date the earliest larvæ left the fruit was October 19, but as these larvæ were not from the earliest eggs deposited and the earliest moths did not oviposit in confinement the band record will show when most of the larvæ cocooned for the winter. The band record for 1911 shows that after August 31 second-brood larvæ were undoubtedly hibernating and that they reached their maximum from September 28 to October 5. The earliest second-brood larvæ probably cocooned the latter part of August and since half-grown larvæ were found in apples on the tree as late as November 30, it is possible that the last stragglers did not cocoon until some time during December, 1911, or January, 1912.

NATURAL ENEMIES OF THE CODLING MOTH.

Parasitic insects.—The egg parasite *Trichogramma pretiosa* Riley may be regarded as a factor in the control of the codling moth in the Santa Clara Valley. In 1909 eggs of the host were collected to obtain records on the parasites. A large number of the Trichogramma issued, but as there was no record of the time when the eggs were laid by the moths or parasitized by the chalcidid, the life cycle of the parasite was not determined. In 1910 the Trichogramma was very abundant, so much so that in the life-history work on the codling moth the jelly glasses in the insectary containing the eggs had to be carefully covered to keep out the parasite. In this year a record was kept relative to the life cycle of the parasite.

Table LI gives notes on the life history of eight parasites.

TABLE LI.—*Life of Trichogramma pretiosa in codling-moth eggs.*

Date eggs laid.	Date parasitism observed.	Date parasite emerged.	Days from deposition of eggs to hatching of parasite.
July 24	Aug. 5	Aug. 19	26
Do.	do.	Aug. 20	27
July 27	Aug. 10	Aug. 23	27
Do.	do.	Aug. 24	28
July 28	Aug. 5	Aug. 19	22
Do.	do.	do.	22
Aug. 1	Aug. 10	Aug. 22	21
Aug. 2	do.	do.	20

The date on which the parasitism was observed can have little to do with the actual date of the parasitization of the egg. As the parasites were very abundant in the vicinity of the eggs it is probable that the latter were stung almost directly after being deposited; consequently the parasites' life cycle would start immediately after the codling-moth eggs had been laid. Figured in this way the life cycle ranges from 20 to 28 days, with an average of 24.16 days. A comparison with the life cycle of the parasite in earlier or first-brood eggs and in eggs of the second brood would be interesting.

In 1909 several parasites were reared from the larvæ of the codling moth by Mr. J. R. Horton, of the Bureau of Entomology. These were all unidentified Hymenoptera. Toward the end of April, 1911, some overwintering full-fed codling moth larvæ were observed by the junior author to have a whitish, distended appearance and upon closer examination proved to have been killed by a hair worm, determined at the instance of Mr. A. L. Quaintance, of the Bureau of Entomology, by Dr. B. H. Ransom, of the Bureau of Animal Industry, as belonging to the family Mermithidæ. These worms, of which there was one in each host, lay coiled up, occupying the entire interior of the larva and exceeding 3 inches in length when uncoiled. None was found in the larvæ of the first or in those of the second broods taken in 1911 from banded trees.

Predaceous insects.—In February, 1911, the larvæ, pupæ, and adults of *Melachius auritus* Lec. were found in considerable numbers, apparently preying upon the larvæ of the codling moth. The specimens, on request of Prof. Quaintance, were later determined by Mr. E. A. Schwarz, of the Bureau of Entomology, who said in reference to them: "* * * This and other species of the same genus have repeatedly been reported to the Bureau of Entomology as enemies of the codling moth. The genus (excepting the imported *Malachius æneus* L.) does not occur in the Atlantic slope of North America."

BAND RECORDS OF 1909.

Through the kindness of Mr. E. Northern, of San Jose, Cal., 20 trees of his orchard were banded to obtain records. The apples are of the Newtown Pippin variety, and the whole orchard, with the exception of the banded trees, is annually treated with several applications of arsenate of lead. The bands were of burlap and were placed at an average of 30 inches from the ground after the loose bark had been scraped off.

A summary of all of the work performed, including the total number of larvæ and pupæ (each collection), the weekly emergence of adults following, and the total number of larvæ which transformed in 1909 and which hibernated until 1911, is shown in Table LII.

TABLE LII.—*Band record for 1909.*

No. of record.	Date of collecting.	Number of—		Total larvæ plus pupæ.	Number of adults emerging from respective collections by—												Total issued, 1909.	Total issued, 1910.
		Larvæ.	Pupæ.		July 15.	July 22.	July 29.	Aug. 5.	Aug. 12.	Aug. 19.	Aug. 26.	Sept. 2.	Sept. 9.	Sept. 16.	Sept. 23.	Sept. 30.		
1......	June 21	1,602	215	1,817	264	378	388	399	402	403	....	....	....	....	....	....	403	(1)
2......	June 28	2,276	79	2,355	0	249	607	646	666	677	678	....	....	....	....	....	678	(1)
3......	July 6	946	159	1,105	0	0	166	628	690	718	722	....	....	....	....	....	722	(1)
4......	July 9	804	93	897	1	8	27	387	411	422	425	426	426	427	....	....	427	122
5......	July 12	761	59	820	0	3	8	159	270	291	294	295	....	....	....	....	295	121
6......	July 15	885	68	953	0	1	2	9	431	484	492	495	495	496	....	....	496	(1)
7......	July 19	919	48	967	0	1	2	6	84	391	418	429	432	432	433	....	433	141
8......	July 22	536	37	573	0	0	0	1	3	200	247	258	259	260	....	....	260	74
9......	July 26	505	30	535	0	0	0	1	2	37	135	140	146	148	....	....	148	143
10......	July 29	350	22	372	0	0	0	0	1	1	66	73	76	78	79	....	79	133
11......	Aug. 2	297	22	319	0	0	0	0	0	2	12	46	47	48	....	....	48	115
12......	Aug. 5	180	16	196	0	0	0	0	0	0	0	2	2	4	....	....	4	42
13......	Aug. 9	185	7	192	0	0	0	0	0	0	0	4	22	25	26	....	26	47
14......	Aug. 12	115	10	125	0	0	0	0	0	0	1	1	5	8	9	....	9	82
15......	Aug. 16	112	4	116	0	0	0	0	0	0	0	0	2	17	18	18	18	55
16......	Aug. 19	262	2	264	0	0	0	0	0	0	0	0	0	103	105	....	105	129
17......	Aug. 23	383	0	383	0	0	0	0	0	0	0	0	0	11	18	....	18	193
18......	Aug. 26	403	3	406	0	0	0	0	0	0	0	0	0	2	4	5	5	223
19......	Aug. 31	477	4	481	0	0	0	0	0	0	0	0	0	1	1	3	3	267
20......	Sept. 2	371	4	375	....	....	....	....	....	....	....	....	....	....	....	....	0	210
21......	Sept. 6	580	0	580	....	....	....	....	....	....	....	....	....	....	....	....	0	257
22......	Sept. 9	381	0	381	....	....	....	....	....	....	....	....	....	....	....	....	0	258
23......	Sept. 13	253	0	253	....	....	....	....	....	....	....	....	....	....	....	....	0	328
24......	Sept. 16	359	1	360	....	....	....	....	....	....	....	....	....	....	....	....	0	157
25......	Sept. 20	290	0	290	....	....	....	....	....	....	....	....	....	....	....	....	0	116

[1] Records annulled through larvæ being drowned in winter.

Figure 36 shows graphically the 1909 band record.

BAND RECORDS OF 1910.

Through the kindness of Mr. W. J. Farrington 12 trees of his orchard at San Jose, Cal., were banded to obtain records of the second-brood larvæ. The apples were of the Skinner Seedling variety; and as this

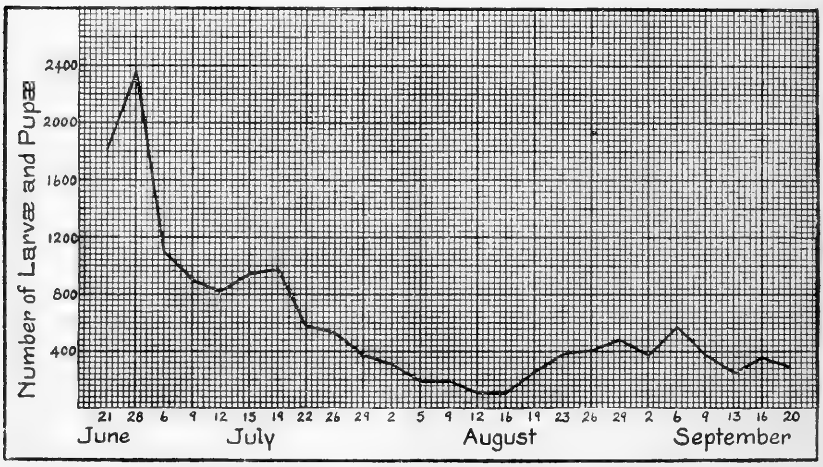

FIG. 36.—Diagram showing band record of 1909. (Original.)

apple ripens early, no records could be taken after August 22, therefore showing practically no second brood of larvæ.

A summary of all the work performed in 1910, including the date of collection, weekly emergence in 1910, and the totals for both 1910 and 1911, is shown in Table LIII.

TABLE LIII.—*Band record for 1910 at San Jose, Cal.*

No. of record.	Date of collecting.	Number of—		Total larvæ plus pupæ.	Number of adults emerging from respective collections by—												Total issued, 1910.	Total issued, 1911.
		Larvæ.	Pupæ.		July 14.	July 21.	July 28.	Aug. 4.	Aug. 11.	Aug. 18.	Aug. 25.	Sept. 1.	Sept. 8.	Sept. 15.	Sept. 22.	Sept. 29.		
1......	June 6	22	6	28	8	8	....	....	....	....	....	....	....	....	....	....	8	0
2......	June 13	76	1	77	26	28	29	29	29	29	32	32	....	....	....	....	32	0
3[1].....	June 27	173	0	173	0	50	60	62	62	62	65	66	67	67	68	68	68	33
4......	July 4	114	3	117	0	2	27	33	39	42	43	43	44	45	45	....	45	34
5......	July 11	326	28	354	0	1	5	36	95	113	117	121	122	123	123	....	123	78
6......	July 18	203	13	216	0	0	1	1	12	53	70	79	80	80	80	....	80	32
7......	July 25	102	9	111	0	0	0	0	0	2	14	21	22	22	23	23	23	22
8......	Aug. 1	41	5	46	0	0	0	0	0	0	2	9	12	12	12	....	12	16
9......	Aug. 8	18	1	19	0	0	0	0	0	0	0	0	0	0	0	....	0	7
10......	Aug. 15	13	5	18	0	0	0	0	0	0	0	0	0	0	2	2	2	7
11......	Aug. 22	20	0	20	0	0	0	0	0	0	0	0	0	0	1	1	1	10

[1] The worms collected June 20 were used for individual pupation records and none of this lot was kept for overwintering emergence, so they are excluded from this table.

Figure 37 shows graphically the 1910 band record.

BAND RECORDS OF 1911.

Ten trees of the Newtown Pippin variety were selected in the orchard of Mr. E. Northern. These trees were banded June 1 with

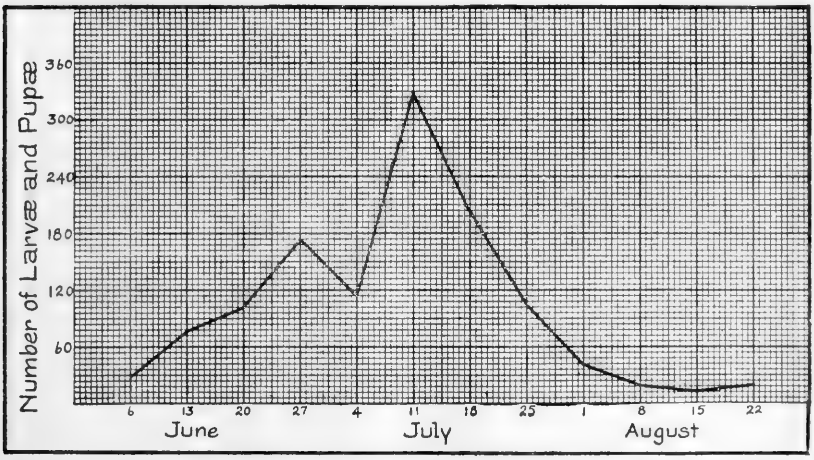

FIG. 37.—Diagram showing band record of 1910. (Original.)

burlap bands of an average width of 8 inches. These trees were left unsprayed while the rest of the orchard was treated with arsenate of lead.

TABLE LIV.—*Band record for 10 apple trees at San Jose, Cal., 1911.*

Date of collection.	Number of larvæ and pupæ.	Date of collection.	Number of larvæ and pupæ.
July 6....	56	Sept. 7...	23
July 13...	91	Sept. 14..	43
July 20...	84	Sept. 21..	73
July 27...	52	Sept. 28..	82
Aug. 3...	40	Oct. 5....	83
Aug. 10..	38	Oct. 12...	64
Aug. 17..	16		
Aug. 24..	15		774
Aug. 31..	14		

From this table and the accompanying diagram, figure 38, there can be observed two clearly defined broods, the first of which reached its maximum about July 16 and the second about October 1. After

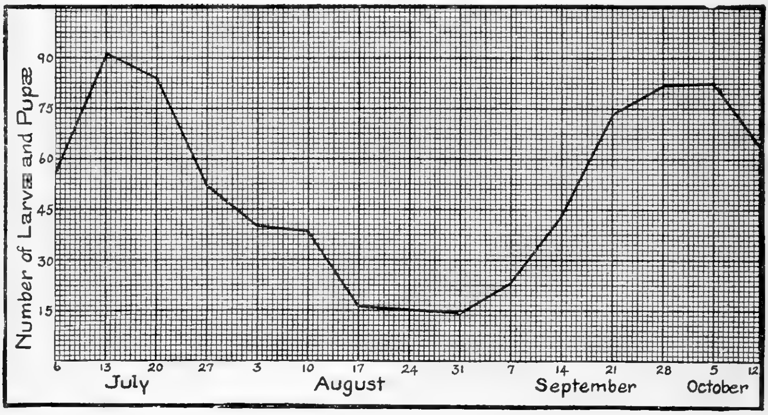

FIG. 38.—Diagram showing band record, Northern orchard, 1911. (Original.)

August 10 only two pupæ were collected, so that it can be safely assumed that all the individuals taken after this date belonged to the second or overwintering brood.

FIRST-BROOD EMERGENCE v. OVERWINTERING EMERGENCE, 1911.

From band records collected in 1911 (see Table LIV) 774 larvæ and pupæ were taken. Some of these, from the first collections, were placed in vials for individual pupal records, while the remainder were placed in jars for adult emergence records. Those placed in the vials were all of the first-brood larvæ and only a very small percentage overwintered. The latter collections—both consisting of first-brood and second-brood larvæ—resulted in an emergence of first-brood moths of about 18 per cent. Only 157 moths emerged from these collections, although a considerable number of pupæ died in their

vials. Compared with seasons 1909–10 and 1910–11 this was a very small proportion of moths for the first brood as against those hibernating as larvæ, for in both these seasons the advantage lay easily with the first brood. According to these data there appears to be an excellent reason to look for a large overwintering emergence in 1912.

REVIEW OF LIFE-HISTORY WORK OF 1911.

Similar records on the life history of the codling moth to those kept in 1910 were obtained in 1911. The results of these observations are shown in the diagram, figure 39. Spring pupæ were present about February 20 and continued until June 20, reaching the maximum about April 12. Moths began to emerge about March 24 and continued until June 8, with the maximum emergence occurring about May 8. Eggs of the first brood were deposited from March 24 until July 11, with the maximum deposition taking place about May 12, while the first-brood larvæ hatched from April 23 until July 26, with the maximum hatching period occurring about May 30. First-brood larvæ cocooned from May 25 until August 26, with the maximum cocooning period about June 28. The first-brood pupæ were present from June 30 until September 29, with a maximum period about July 28. First-brood moths began emerging July 17 and continued until September 29, the maximum emergence taking place August 16.

Second-brood eggs were deposited from July 18 until October 4, with the maximum period about August 28, while the larvæ hatched between July 30 and October 18, with a maximum hatching about September 4. The second-brood larvæ began to cocoon August 14 and on throughout the winter, reaching their maximum about September 18. The overwintering part of the first-brood larvæ commenced to cocoon about June 12, but the majority of the overwintering larvæ came from the second brood. The life cycle from the time the spring pupæ appeared until the last first-brood larvæ cocooned occupied a period of six months.

COMPARISON OF LIFE HISTORY IN 1910 AND 1911.

From a comparison of figures 31 and 39 it is apparent that the main difference exists in the fact that the 1911 season was about two weeks later all through. This is quite to be expected from the colder and later season of 1911. Table LV shows a comparison of the life histories and various stages of the codling moth in 1910 and 1911.

TABLE LV.—*Comparison of life history and stages of the codling moth for 1910 and 1911.*

Year.	Spring pupæ.			First-brood eggs.			First-brood larvæ in fruit.[1]			First-brood pupæ.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1910	61	29	40.7	17	8	12.4	103	31	48.8	55	11	19.04
1911	56	30	42.4	15	10	12.77	42	26	34.67	37	18	23.12

Year.	Life cycle egg to egg.			Second-brood eggs.			Second-brood larvæ in fruit.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1910	101.4	58.4	78.62	17	7	10.92	59	30	40
1911	77	67	71.3	15	11	12.5	79	43	58.15

[1] This is the sum of the length of life in the fruit and the post-larval stage. Consequently the sum of the two maxima, or 103 days, is theoretical, as the maximum life cycle was only 101.4 days. Similarly the sum of the two minima, or 26 days, is also theoretical.

WEATHER RECORDS FOR 1909, 1910, AND 1911.

During the three years that the codling moth has been studied at San Jose, Cal., a comparison of the weather conditions influencing the life-history records has been made. These records have been

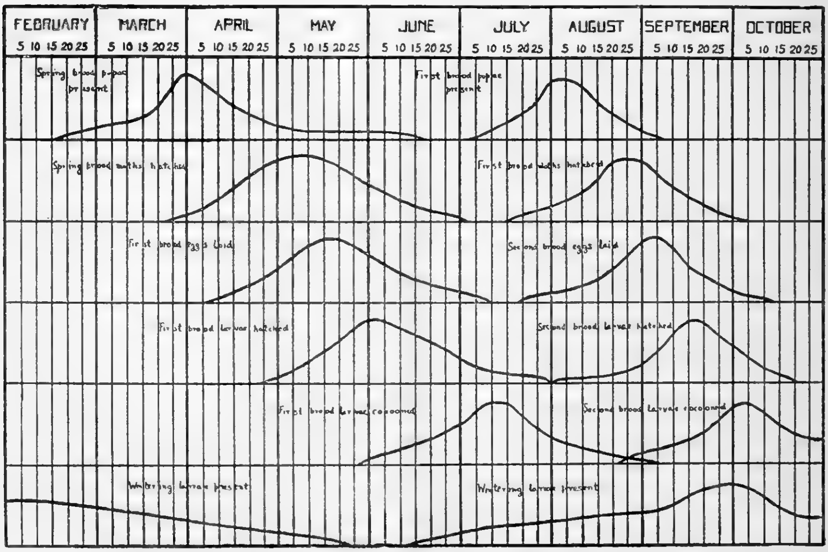

FIG. 39.—Diagram showing seasonal history of the codling moth during the season of 1911. (Original.)

obtained through the United States Weather Bureau Station at San Jose, which is about 3 miles from the laboratory used for studying the codling moth. Table LVI presents the daily mean tempera-

ture for the growing season from February to October, inclusive, for the years 1909, 1910, and 1911; also the mean temperature for the month and the departure from normal.

Table LVII is a summary of Table LVI and shows that in 1909 one month was normal, two were above normal, while the remaining six of the growing season were below normal. The total accumulated mean temperature for the 1909 growing season was 15.9° below the normal, giving an average monthly departure from the normal of −1.76°.

The 1910 season shows four months above the normal and five below, with a total accumulated mean temperature for the growing season of 7.9 below normal, with an average monthly departure from the normal of −0.87°.

The 1911 season shows one month above the normal and the remaining eight below, with a total accumulated mean temperature of 23.7° below normal for the growing season, which gives an average monthly departure from normal of −2.63°.

The 1910 season was much the warmest and 1911 unusually cold—so much so that most stone fruits did not sugar up well. The 1910 season, barring June, which was very cold, was practically a normal growing season.

Looking at the three seasons from a meteorological point of view, one should expect to find the largest percentage of the first-brood larvæ transforming in 1910, with a large second brood indicated by the band record, while 1911 should give the smallest percentage of transforming first-brood larvæ, with a smaller second brood indicated by the band record. The 1909 season should have given a larger percentage of transforming first-brood larvæ than 1911 but less than 1910 and a larger second brood than the 1911 and a smaller one than the 1910 season.

Just what did happen is given under that paragraph comparing the seasonal history of the three years.

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*

Date.	1909	1910	1911	Date.	1909	1910	1911
	°F.	°F.	°F		°F.	°F.	°F.
Feb. 1	56	42	54	Feb. 18	52	46	54
2	58	43	56	19	48	49	48
3	50	41	50	20	47	48	46
4	48	43	52	21	49	48	48
5	47	44	52	22	48	50	48
6	47	44	46	23	52	58	48
7	46	50	44	24	50	56	50
8	46	48	47	25	48	50	44
9	46	52	46	26	50	50	43
10	47	50	49	27	54	49	40
11	54	49	48	28	52	58	42
12	52	51	47				
13	51	56	44	Total av.	50.6	48.7	46.9
14	50	46	40	Departure from normal for month	Normal.	−1.9	−3.7
15	58	46	40				
16	60	48	41				
17	54	48	46				

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*—Continued.

Date.	1909	1910	1911	Date.	1909	1910	1911
	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*	°*F.*
Mar. 1.....	54	60	44	May 1.....	67	51	53
2.....	54	61	47	2.....	60	56	59
3.....	58	60	53	3.....	60	52	54
4.....	47	54	49	4.....	59	52	58
5.....	47	52	52	5.....	58	58	54
6.....	50	52	51	6.....	62	59	54
7.....	50	54	52	7.....	60	63	51
8.....	50	54	57	8.....	56	60	54
9.....	52	60	50	9.....	54	65	56
10.....	54	58	50	10.....	53	60	56
11.....	53	60	51	11.....	53	60	57
12.....	50	52	54	12.....	56	60	56
13.....	50	55	56	13.....	58	58	52
14.....	52	58	58	14.....	58	64	56
15.....	50	57	58	15.....	53	70	54
16.....	50	62	54	16.....	52	71	54
17.....	50	62	53	17.....	53	64	56
18.....	52	56	57	18.....	52	62	56
19.....	48	54	56	19.....	56	62	59
20.....	46	56	52	20.....	53	62	67
21.....	45	52	53	21.....	50	58	68
22.....	47	54	55	22.....	52	63	63
23.....	50	48	56	23.....	52	63	56
24.....	48	48	58	24.....	58	62	52
25.....	52	52	55	25.....	60	64	54
26.....	50	50	53	26.....	60	65	53
27.....	48	46	58	27.....	56	62	58
28.....	50	52	60	28.....	55	64	58
29.....	48	54	65	29.....	60	72	56
30.....	48	58	66	30.....	64	78	58
31.....	53	60	61	31.....	70	72	62
Total av.	50.5	55.3	54.6	Total av.	57.2	62.3	56.5
Departure from normal for month...	−3.2	+1.6	+0.9	Departure from normal for month...	−3.5	+1.6	−4.2
Apr. 1.....	56	58	56	June 1.....	63	65	60
2.....	60	53	56	2.....	63	62	62
3.....	55	56	52	3.....	60	58	62
4.....	47	58	56	4.....	58	58	60
5.....	52	56	60	5.....	56	54	61
6.....	54	56	54	6.....	64	54	60
7.....	58	52	51	7.....	62	57	60
8.....	60	56	56	8.....	58	64	58
9.....	64	56	54	9.....	66	72	62
10.....	54	56	50	10.....	63	62	64
11.....	54	52	49	11.....	60	62	67
12.....	58	56	45	12.....	57	61	60
13.....	58	56	48	13.....	52	54	60
14.....	62	58	52	14.....	56	57	61
15.....	64	62	56	15.....	66	58	64
16.....	62	62	56	16.....	60	58	64
17.....	62	66	60	17.....	56	56	65
18.....	51	59	53	18.....	57	55	68
19.....	50	60	56	19.....	60	58	64
20.....	52	58	56	20.....	62	56	62
21.....	54	61	56	21.....	63	56	55
22.....	56	66	57	22.....	70	56	54
23.....	57	72	57	23.....	78	62	58
24.....	59	68	57	24.....	68	65	58
25.....	58	58	58	25.....	65	70	61
26.....	62	57	50	26.....	64	64	70
27.....	56	54	50	27.....	59	60	62
28.....	56	53	53	28.....	58	58	60
29.....	59	53	50	29.....	56	59	58
30.....	64	54	50	30.....	62	62	64
Total av.	57.1	58.1	53.8	Total av.	61.4	59.8	61.5
Departure from normal for month...	+0.5	+1.5	−2.8	Departure from normal for month...	−3.6	−5.2	−3.5

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*—Continued.

Date.	1909	1910	1911
	°*F.*	°*F.*	°*F.*
July 1.....	66	56	70
2.....	61	57	67
3.....	60	56	65
4.....	56	64	64
5.....	60	66	68
6.....	61	70	66
7.....	66	71	66
8.....	62	70	70
9.....	64	68	68
10.....	64	67	66
11.....	68	65	68
12.....	73	67	66
13.....	68	66	64
14.....	68	66	66
15.....	68	63	68
16.....	62	66	68
17.....	60	70	64
18.....	62	72	62
19.....	56	74	62
20.....	66	71	61
21.....	63	65	60
22.....	68	66	62
23.....	64	66	64
24.....	65	62	65
25.....	63	66	71
26.....	61	64	68
27.....	66	64	65
28.....	66	65	66
29.....	65	64	66
30.....	64	62	70
31.....	65	60	67
Total av.	63.8	65.5	65.8
Departure from normal for month...	−3.1	−1.4	−1.1
Aug. 1....	67	62	62
2....	66	65	64
3....	68	62	66
4....	68	64	62
5....	62	66	62
6....	67	65	63
7....	62	62	62
8....	64	64	60
9....	64	62	60
10....	61	63	61
11....	60	60	61
12....	58	62	58
13....	61	66	58
14....	63	65	59
15....	63	66	59
16....	68	68	60
17....	73	62	60
18....	70	62	62
19....	68	63	62
20....	66	60	66
21....	63	64	61
22....	60	69	66
23....	62	72	63
24....	66	70	66
25....	70	66	63
26....	68	65	62
27....	68	60	63
28....	62	61	62
29....	62	68	68
30....	59	67	69
31....	63	64	64
Total av.	64.6	64.4	62.4
Departure from normal for month...	−2.1	−2.3	−4.3
Sept. 1....	64	64	62
2....	62	63	62
3....	64	60	62
4....	64	64	62
5....	62	62	61
6....	64	61	62
7....	63	60	65
8....	68	61	60
9....	69	66	60
10....	63	67	58
11....	67	59	60
12....	70	56	60
13....	70	58	62
14....	72	60	66
15....	74	62	63
16....	73	60	62
17....	65	62	64
18....	64	58	64
19....	62	62	62
20....	62	62	63
21....	66	64	58
22....	68	65	63
23....	62	64	64
24....	64	63	57
25....	59	62	58
26....	64	62	58
27....	63	59	56
28....	62	60	59
29....	60	66	63
30....	56	68	58
Total av.	64.8	62.0	61.0
Departure from normal for month...	+0.1	−2.7	−3.7
Oct. 1.....	54	60	56
2.....	60	59	56
3.....	56	58	56
4.....	60	62	55
5.....	62	64	56
6.....	60	70	60
7.....	60	72	67
8.....	64	70	60
9.....	68	56	55
10.....	70	55	55
11.....	66	54	59
12.....	62	56	60
13.....	60	61	58
14.....	61	58	62
15.....	54	58	66
16.....	56	62	68
17.....	58	69	68
18.....	56	66	67
19.....	61	66	64
20.....	64	64	58
21.....	60	60	56
22.....	59	56	55
23.....	62	60	56
24.....	64	61	62
25.....	62	63	64
26.....	56	62	52
27.....	54	62	56
28.....	54	60	55
29.....	51	59	56
30.....	50	57	57
31.....	52	58	56
Total av.	59.3	61.2	59.0
Departure from normal for month...	−1.0	+0.9	−1.3

TABLE LVII.—*A summary of Table LVI, showing the departures from normal of the average mean temperature for the growing season 1909, 1910, 1911, at San Jose, Cal.*

Month.	Departure from normal in—		
	1909	1910	1911
	°*F.*	°*F.*	°*F.*
February	Normal.	−1.9	− 3.7
March	− 3.2	+1.6	+ .9
April	+ .5	+1.5	− 2.8
May	− 3.5	+1.6	− 4.2
June	− 3.6	−5.2	− 3.5
July	− 3.1	−1.4	− 1.1
August	− 2.1	−2.3	− 4.3
September	+ .1	−2.7	− 3.7
October	− 1.0	+ .9	− 1.3
Total	−15.9	−7.9	−23.7
Average monthly departure from normal	− 1.76	− .87	− 2.63

COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASON OF 1909, 1910, AND 1911.

The temperature conditions (see Table LVI) indicated that 1910 was a very warm season favorable for the development of the codling moth, while the 1911 season was very cold and unfavorable to this insect, with 1909 an intermediate season. The 1910 season, while apparently very warm, was a more normal season than the other two.

On account of many lacking life-history records in 1909 but with a good band record, and a poor band record in 1910 but with complete life-history records, it is impossible to make perfect comparisons of the three seasons. An examination of both band records and rearing experiments shows the following data, however. (See Table LVIII.)

TABLE LVIII.—*Summary of the band records for 1909, 1910, and 1911 along with rearing results, showing the comparative size of the broods and relative number of transforming and wintering larvæ.*

Larval collections.	Percentages for—		
	1909	1910	1911
Transforming larvæ—total band collection	27.6	(1)	18.0
Wintering larvæ—total band collection	72.4	(1)	82.0
Relative proportion of first-brood larvæ	95.0	[2] +50.0	50.0
Relative proportion of second-brood larvæ	5.0	[2] +50.0	50.0
Transforming larvæ of first brood	33.5	33.4	40.0
Wintering larvæ of first brood	66.5	66.6	60.0

[1] Band record from summer apples. [2] Approximately (from rearing records).

The results as indicated by Table LVIII are not entirely in conformity with expectations.

The relative proportions for the broods for 1909 and 1910 appear correct in comparison with the weather conditions, but the relative proportions for 1911 seem incorrect after examining the weather condi-

tions for that year. Theoretically, on account of the very cold season there should have been a large first brood and a small second brood, which is further borne out by the small percentage of transforming larvæ of the total band collection. One fact is evident, however, there were more codling-moth larvæ present in the field in 1909 and 1910, which gave a larger series in the band records for these years in comparison with 1911.

The 1911 season was apparently so cold early that moths did not oviposit properly and the temperature conditions probably exerted such an influence that the infestation was light, therefore cutting down both broods and making them nearly equal.

CONTROL OF THE CODLING MOTH ON PEARS AND APPLES IN THE SANTA CLARA VALLEY.

While prunes, apricots, and cherries are the chief fruits raised in this valley, there are about 500 acres set to apples and 1,400 acres to pears. These orchards on the whole have probably paid better financially the past five years than many orchards of the first three varieties of fruits. Situated as they are, on the lower and wet but rich soils near Alviso, they have escaped the attacks of the chief insect pest to deciduous fruits in central California, the pear thrips (*Euthrips pyri* Daniel). The codling moth aside from several species of plant-lice, has been practically the only insect worthy of the attention of apple and pear growers in the Santa Clara Valley.

It is needless to say that spraying, both good and bad, has been practiced for the codling moth, but the majority of the fruit growers have either sprayed at the wrong time or in an indifferent manner or have used ineffective poisons.

The writers have seen apple orchards that had been sprayed three times during the season and these had from 75 to 80 per cent wormy fruit. Until the past two or three years there was a tendency to do slipshod work at low pressure, and even now many growers try to use too many leads of hose and to cover more trees with too little material. The practice of using four lines of hose on one spray outfit should be discouraged since it is difficult to maintain a sufficiently high pressure and the nozzle men frequently interfere with one another. It would be much better business to use more spray outfits, and even to spray from a tower.

Data are presented here from one apple orchard and one pear orchard where the spraying was done after the directions of this bureau. On both orchards the work was in the nature of a commercial demonstration and it is in a way unfortunate that no checks could be obtained on the pear orchard, which was sprayed two successive years, although the early history of the place is known.

THE O'TOOLE PEAR ORCHARD AT ALVISO, CAL.

This orchard lies on a road intersecting the Alviso and Milpitas Roads about 6 miles north of San Jose and is, strictly speaking, in the Alviso section of the Santa Clara Valley. The soil is entirely "made soil," the orchard itself being surrounded by a high levee. The type of soil is a very rich sandy loam styled "Fresno sandy loam" on the map by the United States Geological Survey. This orchard, 30 acres in extent, is composed of six varieties of pears and the trees are some of the finest in the State of California, many of them reaching a diameter of 8 to 10 inches at the base.

During the years 1910 and 1911 the writers have, through the courtesy of Mr. George Reed, manager of this orchard for the Anderson Fruit Co., been able to obtain figures on the wormy and nonwormy fruit. Mr. Reed, in talking with the authors, stated that the orchard usually contained from 15 to 60 per cent wormy fruit before it was placed in his hands, even when sprayed for the codling moth. The early Bartlett pears were seldom extremely wormy, but late varieties, such as the Winter Nelis and Easter Beurré, frequently had more wormy pears than clean ones.

One peculiar fact relating to this orchard should be mentioned here. The west and north sides are closed in by a levee of the Coyote Creek, which is about 10 feet high. This has caused the orchard to blossom and mature its fruit about 10 days earlier than other orchards in the vicinity and has therefore made earlier spraying necessary also.

Spraying operations.—A power outfit was used both years at a high pressure and arsenate of lead as a poison at the rate of 2 pounds to 50 gallons of water. An old spraying outfit was used in 1910 and a new one in 1911; consequently much better work was done in the latter year.

In all of the spraying large-chamber nozzles were used, one to each spray rod. All of the work was done from the ground, the men using 12-foot rods and 50-foot lengths of hose.

Since no check on the spraying was left, no figures are presented here on the cost of spraying and the benefit derived, but a summary is given of the wormy and sound fruit of the trees examined under each variety.

Season of 1910.—The fallen fruit was collected under five trees weekly throughout the season and examined for the entrance place of the worms on each of the six varieties. (See Table LIX.)

TABLE LIX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1910.*

DATES OF SPRAYING: APR. 5, MAY 4, AND MAY 23.

Variety of pear and number of trees.	Fruit on ground.						Fruit on tree.						Total not wormy.	Total wormy.	Total fruit.	Percentage wormy on ground.	Percentage wormy on tree.	Total percentage wormy.
	Not wormy.	Wormy.	Where worms entered.			Total.	Not wormy.	Wormy.	Where worms entered.			Total.						
			Calyx.	Side.	Stem.				Calyx.	Side.	Stem.							
Vicars:																		
Tree 1	162	12	3	9	0	174	620	3	0	3	0	623	782	15	797	6.97	0.48	1.79
Tree 2	91	39	12	26	1	130	1,411	25	16	9	0	1,436	1,502	64	1,566	30.00	1.74	4.09
Tree 3	324	28	8	20	0	352	1,148	11	8	2	1	1,159	1,472	39	1,511	7.96	.95	2.58
Tree 4	16	17	0	17	0	33	823	14	3	11	0	837	839	31	870	51.52	1.67	3.56
Tree 5	185	20	1	19	0	205	1,145	13	3	10	0	1,158	1,330	33	1,363	9.76	1.12	2.42
Trees 1-5 combined	778	116	24	91	1	894	5,147	66	30	35	1	5,213	5,925	182	6,107	12.97	1.26	2.98
Comice:																		
Tree 1	315	8	2	6	0	323	775	8	4	3	1	783	1,090	16	1,106	2.47	1.02	1.44
Tree 2	265	2	1	1	0	267	282	2	2	0	0	284	547	4	551	.75	.70	.73
Tree 3	198	2	1	1	0	200	330	16	11	4	1	346	528	18	546	1.00	4.62	3.29
Tree 4	322	14	4	9	1	346	581	14	13	1	0	595	913	28	941	4.05	2.19	2.98
Tree 5	360	9	2	7	0	369	693	20	17	3	0	713	1,053	29	1,082	2.44	2.80	2.68
Trees 1-5 combined	1,470	35	10	24	1	1,505	2,661	60	47	11	2	2,721	4,131	95	4,226	2.33	2.21	2.24
Bartlett:																		
Tree 1	81	14	8	6	0	95	1,330	22	7	14	1	1,352	1,411	36	1,447	14.73	1.63	2.48
Tree 2	94	9	4	4	1	103	1,594	22	10	10	2	1,616	1,688	31	1,719	8.73	1.39	1.80
Tree 3	36	10	6	4	0	46	900	15	10	3	2	915	936	25	961	21.74	1.64	2.60
Tree 4	88	36	21	13	2	124	1,082	26	14	12	0	1,108	1,170	62	1,232	29.03	2.34	5.03
Tree 5	76	11	4	7	0	87	964	3	0	3	0	967	1,040	14	1,054	12.64	.31	1.33
Trees 1-5 combined	375	80	43	34	3	455	5,870	88	41	42	5	5,958	6,245	168	6,413	17.58	1.47	2.62
Clargeau:																		
Tree 1	68	28	9	17	2	96	449	7	2	5	0	456	517	35	552	29.17	1.53	6.34
Tree 2	101	19	4	15	0	120	232	4	0	4	0	236	333	23	356	15.83	1.69	6.46
Tree 3	77	23	13	10	0	100	904	3	3	0	0	907	981	26	1,007	23.00	.33	2.58
Trees 1-3 combined	246	70	26	42	2	316	1,585	14	5	9	0	1,599	1,831	84	1,915	22.15	.87	4.38

TABLE LIX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1910*—Continued.

DATES OF SPRAYING: APRIL 5, MAY 4, AND MAY 23—Continued.

Variety of pear and number of trees.	Fruit on ground.						Fruit on tree.						Total. not wormy.	Total wormy.	Total fruit.	Per-centage wormy on ground.	Per-centage wormy on tree.	Total per-centage wormy.
	Not wormy.	Wormy.	Where worms entered.			Total.	Not wormy.	Wormy.	Where worms entered.			Total.						
			Calyx.	Side.	Stem.				Calyx.	Side.	Stem.							
Winter Nelis:																		
Tree 1	53	14	4	8	2	67	713	12	8	3	1	725	766	26	792	20.89	1.65	3.28
Tree 2	39	30	9	18	3	69	564	16	8	6	2	580	603	46	649	43.48	2.76	7.09
Tree 3	21	14	1	11	2	35	393	15	7	4	4	408	414	29	443	40.00	3.65	6.54
Tree 4	4	9	3	6	0	13	663	11	4	7	0	674	667	20	687	69.23	1.63	2.91
Trees 1-4 combined	117	67	17	43	7	184	2,333	54	27	20	7	2,387	2,450	121	2,571	36.41	2.26	4.70
Easter Beurré:																		
Tree 1	216	33	5	26	2	249	1,357	25	5	16	4	1,382	1,573	58	1,631	13.25	1.80	3.55
Tree 2	138	27	8	17	2	165	670	32	11	18	3	702	808	59	867	16.36	4.56	6.80
Tree 3	206	29	4	20	5	235	1,139	61	17	35	9	1,200	1,345	90	1,435	12.34	5.08	6.27
Tree 4	287	35	3	28	4	322	1,222	20	5	13	2	1,242	1,509	55	1,564	10.87	1.61	3.61
Tree 5	265	21	3	17	1	286	725	8	1	2	5	733	990	29	1,019	7.34	1.09	2.84
Trees 1-5 combined	1,112	145	23	108	14	1,257	5,113	146	39	84	23	5,259	6,225	291	6,516	11.53	2.77	4.46

Table LIX shows the detailed summaries of this work and that the five trees of Vicar pears averaged 2.98 per cent wormy fruit, including windfalls. The Doyenne du Comice averaged 2.24 per cent wormy, the Bartlett 2.62 per cent, the Buerré Clargeau 4.38 per cent, the Winter Nelis 4.70 per cent, and the Easter Buerré 4.46 per cent. It should be noted that the last three varieties show nearly twice the wormy fruit that the other varieties do. This can be explained by the fact that they are later in maturing and hence give the second brood of the codling moth a much better chance to work. The senior author has frequently observed that Bartlett pears in the Santa Clara Valley usually escape nearly all of the second brood of codling moth by being picked so early. A comparison of the dates of spraying with the life-history records will show that most of the spraying was timed a little early, even allowing 10 days because it is an extremely early orchard.

Season of 1911.—This year the spraying was accomplished in a more through manner and at a more opportune time, the first application from April 12 to 15, or just as most varieties were shedding the petals; the second application from June 1 to 4; and the third from July 5 to 9. Only two trees were examined in each variety and the work was done weekly as in 1910. All the fruit at picking time on the indicated trees was examined.

Table LX gives a summary of the work performed.

TABLE LX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1911.*

DATES OF SPRAYING: APRIL 12-15, JUNE 1-4, AND JULY 5-9.

Variety of pear and No. of tree.	Fruit on ground.						Fruit on tree.						Total not wormy.	Total wormy.	Total fruit.	Percentage wormy on ground.	Percentage wormy on tree.	Total percentage wormy.
	Not wormy.	Wormy.	Where worms entered.			Total.	Not wormy.	Wormy.	Where worms entered.			Total.						
			Calyx.	Side.	Stem.				Calyx.	Side.	Stem.							
Vicars:																		
Tree 1	41	10	3	6	1	51	1,084	16	6	9	1	1,100	1,125	26	1,151	19.0	1.45	2.16
Tree 2	4	0	0	0	0	4	312	3	2	1	0	315	316	3	319	.0	.95	.94
Trees 1-2 combined	45	10	3	6	1	55	1,396	19	8	10	1	1,415	1,441	29	1,470	18.18	1.34	1.97
Comice:																		
Tree 1	6	1	1	0	0	7	....	....	....	....	....	....	....	....	....	14.28	....	....
Tree 2	35	3	1	2	0	38	289	5	1	3	1	294	324	8	332	7.89	1.70	2.40
Trees 1-2 combined	41	4	2	2	0	45	289	5	1	3	1	294	330	9	339	8.89	1.70	2.65
Bartlett:																		
Tree 1	19	2	1	1	0	21	1,114	9	4	5	0	1,123	1,133	11	1,144	9.52	.80	.96
Tree 2	100	0	0	0	0	100	1,010	5	5	0	0	1,015	1,110	5	1,115	.0	.49	.45
Trees 1-2 combined	119	2	1	1	0	121	2,124	14	9	5	0	2,138	2,243	16	2,259	1.65	.65	.70
Clargeau:																		
Tree 1	29	1	1	0	0	30	813	7	5	2	0	820	842	8	850	3.33	.85	.94
Tree 2	2	0	0	0	0	2	197	0	0	0	0	197	199	0	199	.0	.0	.0
Trees 1-2 combined	31	1	1	0	0	32	1,010	7	5	2	0	1,017	1,041	8	1,049	3.12	.69	.76
Winter Nelis:																		
Tree 1	12	1	0	1	0	13	997	3	3	0	0	1,000	1,009	4	1,013	7.7	.30	.39
Tree 2	20	1	0	1	0	21	1,837	2	1	1	0	1,839	1,857	3	1,860	4.76	.11	.16
Trees 1-2 combined	32	2	0	2	0	34	2,834	5	4	1	0	2,839	2,866	7	2,873	5.88	.17	.24
Easter Buerré:																		
Tree 1	131	1	0	1	0	132	1,115	2	0	2	0	1,117	1,246	3	1,249	.75	.18	.24
Tree 2	44	0	0	0	0	44	809	2	0	2	0	811	853	2	855	.0	.246	.245
Trees 1-2 combined	175	1	0	1	0	176	1,924	4	0	4	0	1,928	2,099	5	2,104	.56	.21	.237

This year, 1911, all of the varieties yielded a larger percentage of clean fruit, the Vicars averaging 1.97 per cent wormy, the Doyenne du Comice 2.65 per cent, the Bartletts 0.70 per cent, the Buerré Clargeau 0.76 per cent, the Winter Nelis 0.24 per cent, and the Easter Buerré 0.237 per cent.

Probably one of the reasons the later varieties were as free from worms in 1911 as the early varieties was that the third application for second-brood larvæ was better timed and was more thorough.

THE NORTHERN APPLE ORCHARD.

Season of 1911.—Through the courtesy of Mr. E. Northern the writers were able to examine weekly 5 sprayed and 5 unsprayed apple trees of the Newtown Pippin variety for wormy fruit. All of Mr. Northern's orchard of 11 acres was sprayed by him with a hand outfit at fair pressure except 5 trees unsprayed left for a check. While it is hardly fair to compare the work of a hand outfit with that of a power outfit, Mr. Northern obtained excellent results, although with a much higher percentage of wormy fruit than Mr. Reed obtained on his pear orchard.

The spraying was done on May 9, June 9, and July 26. The whole orchard was in full bloom by April 18, and by May 1 nearly all the trees had dropped their petals. In all the spraying 2 pounds of arsenate of lead were used to 50 gallons of water and with no fungicide.

Table LXI shows the details of the results obtained on the "Northern orchard."

TABLE LXI.—*Results of spraying for codling moth on apples, Mr. E. Northern's orchard, season of 1911. Variety, Newtown Pippin.*

SPRAYED MAY 9, JUNE 9, AND JULY 25

No. of tree.	Windfalls.						Fruit on tree.						Total not wormy.	Total wormy.	Total fruit.	Percentage wormy on ground.	Percentage wormy on tree.	Total percentage wormy.
	Not wormy.	Wormy.	Where worms entered.			Total.	Not wormy.	Wormy.	Where worms entered.			Total.						
			Calyx.	Side.	Stem.				Calyx.	Side.	Stem.							
Tree 1	335	37	15	18	4	372	385	13	5	7	1	398	720	50	770	9.94	3.26	6.49
Tree 2	454	41	6	26	9	495	635	69	21	42	6	704	1,089	110	1,199	8.28	9.8	9.17
Tree 3	275	31	9	17	5	306	243	22	6	9	7	265	518	53	571	10.03	8.3	9.28
Tree 4	592	99	25	66	8	691	417	69	26	39	4	486	1,009	168	1,177	14.32	14.19	14.27
Tree 5	769	80	39	33	8	849	806	83	28	44	11	889	1,575	163	1,738	9.42	9.33	9.37
Trees 1–5 combined	2,425	288	94	160	34	2,713	2,486	256	86	141	29	2,742	4,911	544	5,455	10.61	9.33	9.97
UNSPRAYED.																		
Tree 1a	74	374	182	161	31	448	125	112	49	54	9	237	199	486	685	83.48	47.26	70.94
Tree 2a	111	426	212	177	37	537	163	108	46	52	10	271	274	534	808	79.33	39.86	66.09
Tree 3a	46	55	24	26	5	101	41	17	6	9	2	58	87	72	159	54.45	29.31	45.28
Tree 4a	205	971	460	435	76	1,176	268	457	214	208	35	725	473	1,428	1,901	82.57	63.03	75.11
Tree 5a	150	982	539	358	85	1,132	140	354	178	148	28	494	270	1,336	1,626	86.75	71.83	82.16
Trees 1a–5a combined	586	2,808	1,417	1,157	234	3,394	737	1,048	493	471	84	1.785	1,323	3,856	5,179	82.73	58.71	74.45

The five sprayed trees under observation show a range in wormy fruit from 6.49 to 14.27 per cent, with an average of 9.97 per cent, while the five unsprayed trees ranged from 45.28 to 82.16 per cent wormy fruit.

The five sprayed trees averaged 90.03 per cent sound fruit, while the checks averaged only 25.45 per cent sound fruit, the spraying thus giving a benefit of 64.58 per cent sound fruit on the sprayed trees.

It is evident that the second brood of larvæ caused a large percentage of wormy fruit both on the sprayed and unsprayed trees. The wormy fruit on the five sprayed trees at picking time ranged from 14.19 per cent, and since most of the apples affected by the first brood had fallen off before this nearly all of the injury can be charged to the second-brood larvæ.

CONCLUSIONS FROM EXPERIMENTS IN CONTROL.

Two orchards, one of pears and one of apples, which had been sprayed for the codling moth according to the recommendation of this bureau, show conclusively the advantage derived from this treatment.

The pear orchard shows more decided results than the apple orchard because of more thorough work with a power outfit at high pressure.

The second year's treatment on the pear orchard shows to advantage because of better work and timing of the applications.

Two years' observations have shown that three applications of arsenate of lead in the Santa Clara Valley at about 2 pounds to 50 gallons are necessary for pears and apples, except on Bartlett pears, where two would be sufficient.

The first application should be made just after the blossom petals fall, and the date may vary from early April to the first few days in May, depending upon the variety of fruit and the season; the second application should be made about from 2 to 3 weeks after the first application, and usually falls in June; the third application should be applied about from 3 to 4 weeks after the second, and usually falls in July.

Arsenate of lead can be used on pears along with the treatment recommended for pear-thrips larvæ, and the distillate-oil emulsion seems to give the poison a smoother surface tension so that it spreads more readily on the foliage and holds up longer in suspension while in the spray tank. The arsenate of lead should be mixed separately and added last to the spray tank after the distillate-oil emulsion and tobacco extract have been combined.

A power outfit should be used in spraying, maintaining 200 pounds pressure. Bordeaux nozzles equipped with an angle and used from a tower give the highest percentage of clean fruit.

SUMMARY.

In the Santa Clara Valley of California there occurs one full generation and one partial generation of the codling-moth larvæ.

The following is a brief summary of the life cycle: The overwintered larvæ pupate from the middle of February until May, the moths issuing about six weeks later through a period extending from the latter part of March until the middle of June. Eggs are deposited about 3 days after emergence, and these hatch in about 12 days, the red ring appearing in 2 or 3 days and the black spot some 8 days later. The first-brood larvæ enter the fruit shortly after hatching and remain there for about 5 weeks. They are present in the fruit from the last week in April until the last week in July, a range of 3 months, or nearly three times their average larval life. After leaving the fruit the full-grown larva seeks some crevice in the bark on the main trunk or on the larger limbs of the tree and there spins its cocoon, transforming after a few days into a pupa. In confinement a great variation occurs in the time between spinning the cocoon and actual pupation, but in the field there is probably not nearly such a variation. The first-brood pupal stage averages 21 days, only half as long as the corresponding stage of the spring brood, a fact due, undoubtedly, to the considerably higher temperature influencing the former brood of pupæ. First-brood pupæ are present from about the middle of June until the middle of September, although the two years 1910 and 1911 (see figs. 31 and 39) show a considerable diversity on this point; for in 1910, the warmer of the two years, the first-brood pupæ were present three weeks earlier. Similarly the first-brood moths emerged just so much earlier in 1910. A fair proportion of the first-brood pupæ overwinter, and for this reason some individuals remain in the immature forms for 10 or 11 months. The first-brood moths begin to deposit eggs 3 days after issuing, and these eggs hatch in 11 days, or if the season is cold in 12 or 13 days. The red circle and black spot appear as in the first-brood eggs. The second-brood larvæ remain in the fruit about 50 days, and they are present from the latter half of July until the middle of October, a period of about 80 days, and thus shorter in comparison to the length of the larval stage than in the first-brood larvæ. This is accounted for by the shorter period of adult emergence, causing a shorter period of egg deposition in the first-brood moths as compared with that of the spring-brood moths. All larvæ of the second brood winter over and form the great bulk of overwintering larvæ. Doubtless if the

fruit remained longer on the tree there would be a complete second brood possible, since so many varieties of apples and pears are picked before the end of September. In 1909 the second generation exceeded the first and this was a cold year, while in 1910 and 1911 the two generations were about equal in numbers, in spite of the fact that the former was a warm, the latter a cold, year. In 1910 there was good reason to expect a large second generation, considerably greater in relation to the first generation than in 1911, but the relative proportions of the two generations was not maintained in 1910. Consequently it may be inferred that the weather does not always exert great influence on the relative sizes of the two generations any more than a large number of individuals of the first brood does on the second.

The relative number of larvæ of the first brood that overwinter varies from year to year, but not entirely owing to influence exerted by the weather or the temperature.

The larvæ of the second brood are present in all but the earliest varieties of fruit, and it is necessary to combat them.

Weather conditions exert more influence on the spring emergence of moths than on the summer emergence.

The sex of the moth can be determined in the larval stage by the presence or absence of the two testes, which are black and in the male show through the skin on the dorsum of the eighth segment.

Three applications of the poison spray are necessary for the control of the codling moth in this locality. The first should be made immediately after the petals have dropped from the blossoms, the second should follow from 2 to 4 weeks later, and the third a month or 6 weeks after the second.

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